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Technical Report No. BDM/M-011-79

⑩ Terrence P. Goddard

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Volume I.

⑥ SIMPLE MODELS OF COMBAT. Draft for Battle

⑨ Final Report. Vol. I

Draft for Battle Book II

May 78-May 79

Book II.

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FOREWORD

The work described in this report was performed under Contract
MDA 903-78-C-0314 for the Tactical Technology Office of the Defense Advanced
Research Projects Agency. It is part of a continuing effort to develop
simplified, manual models of land combat that are useful to the field
commander as well as the analyst.

The original "Commander's Battle Book" was published in 1976 and
utilized a range-averaged Lanchestrian kill rate methodology to compute
minute-by-minute loss exchanges in a battalion level armor/antiarmor battle.
The present effort introduces range dependency, improved kill rate parameters
derived from force-on-force test data, red artillery effects, and reduced
visibility into the Battle Book methodology. This Final Report, Volume I
is a draft of "Battle Book II", which incorporates these improvements.

A companion Volume II summarizes an analysis of force-on-force field
experiment data that were used to improve Battle Book kill rate parameters.

to p. 2

SECTION 1

OVERVIEW OF THE
BATTLE BOOK METHOD

OVERVIEW OF THE BATTLE BOOK CALCULUS METHOD

> Battle Book Calculus is a map-based minute-by-minute loss
> exchange analysis of battalion combat.

Cont.
Battle Book Calculus is a map-based dynamic combat analysis that
examines minute-by-minute movement and loss exchanges for a battalion-level
battle. Tactically realistic attack and defense combat activity are
modeled in such a manner that all dynamic combat operations and results are
lucid to the commander or analyst conducting the play. The method exploits
the emerging base of data on the rates of combat processes now becoming
available through force-on-force testing conducted at CDEC and other testing
agencies.

The method is map-oriented, and, while it could be almost totally
automated, it is primarily and deliberately a manual method. By means of a
minute-by-minute assessment of the unfolding battle as displayed on a map,
the analyst gains an intimate understanding of the battle dynamics and
interactions under study, and has the opportunity, at each minute, to exercise
judgment with regard to fire distribution, withdrawal to new positions, and
other tactics as would be done in the real battle by the military commander.
Actions occur in realistic time sequences using the tactical doctrines and
weapon systems of the opposing forces.

The basic method is comprised of three major tasks:

(1) Formulation of a map based battalion level battle plan based on
     actual terrain, defensive positions, and attacker force strength.

(2) Calculation and tabulation of kill rates (in kills/minute) for
     each important armor/antiarmor weapon pair.

(3) Dynamic battle play, involving minute-by-minute movement and
     calculation of loss exchange.

BATTLE BOOK CALCULUS INVOLVES
THREE MAJOR STEPS

MAP BASED
BATTLE PLAN

● It is a map-based method which
provides tactically realistic
attack and defense combat
activities on actual terrain.

WEAPON
KILL RATE
ANALYSIS

● It utilizes weapon-by-weapon
analysis to understand armor/
antiarmor system performance.
Range dependent kill rates are
calculated for each weapon pair,
based on system lethality and
vulnerability data and field
experiment data.

DYNAMIC
COMBAT
PLAY

● Minute-by-minute movement and
calculation of loss exchanges
elucidates the dynamic combat.

BATTLE PLANNING

The battle planning process must start with a complete description of the order of battle. Sufficiently detailed data must be obtained to accurately describe the battalion test force plans and operations in view of the general situation across the front. This documentation would normally include a statement of mission, force deployments and task organizations, threat description, concept of the battle, coordination plans, C^3, supporting maps and overlays, artillery fire support plans, attack helicopter fire support plans, mine and barrier plans, and service support.

The detailed company level battle planning is shown schematically in the accompanying chart.

In Step 1 the battle area is located on a 1:25,000 scale topographic map.

In Step 2 the detailed plan is formulated on an acetate overlay of the map. The defending hard points and actual weapon (from 8 digit coordinates) positions are marked on the overlay. Company level attack routes are then drawn in on the overlay, and time ticks representing company progress or overwatch fire positions marked along the routes. The time advance and routing accounts for natural and defensive barriers such as dikes, tank barriers, and minefields, and for ground condition. When removed from the map, Step 3, the overlay is a time-stepped attack summary.

In Step 4, individual defensive weapon coverage diagrams, with range bands, are positioned on the attack summary overlay. The times and ranges at which individual attacking company routes are intervisible with the defending weapon are recorded and transcribed, in Step 5, onto a summary chart, giving engagement opportunity statistics.

The engagement opportunity statistics diagram is a time history of the intervisibility of all ground-based armor/antiarmor weapon pairs.

BATTLE PLANNING METHODOLOGY PRODUCES A
TIME HISTORY OF ARMOR/ANTIARMOR WEAPON INTERVISIBILITY
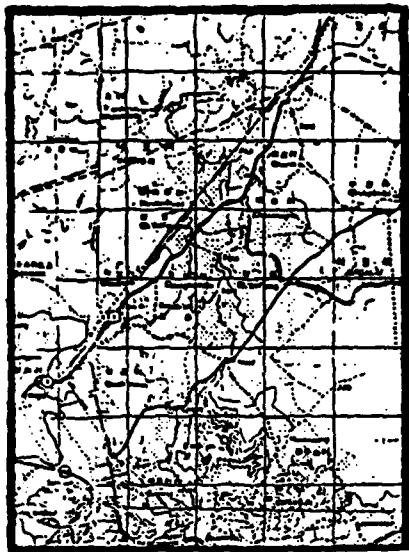
1:25,000 MAP OF
BATTLE AREA
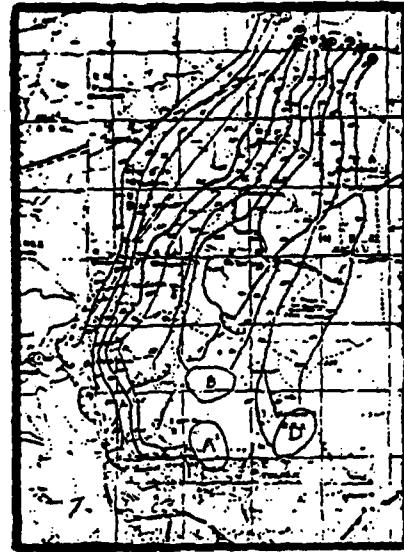
COMPANY ATTACK ROUTES AND
DEFENDING POSITIONS MARKED ON
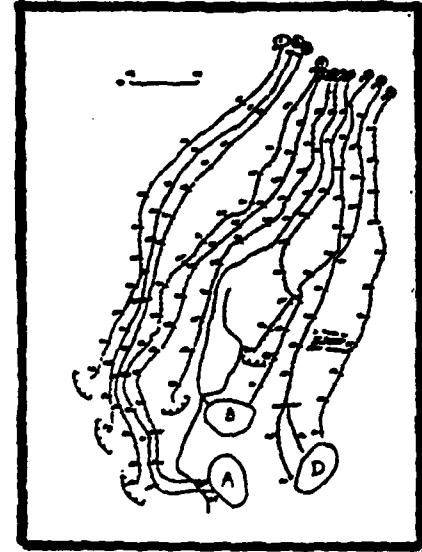
BATTLE SUMMARY
OVERLAY
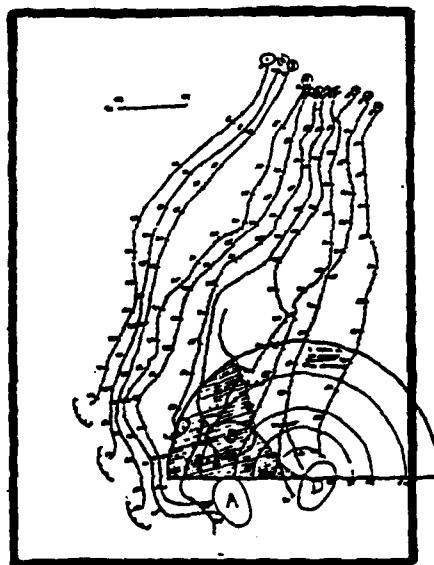
COVERAGE DIAGRAM OVERLAY
SHOWS ATTACKER/DEFENDER
INTERVISIBILITY
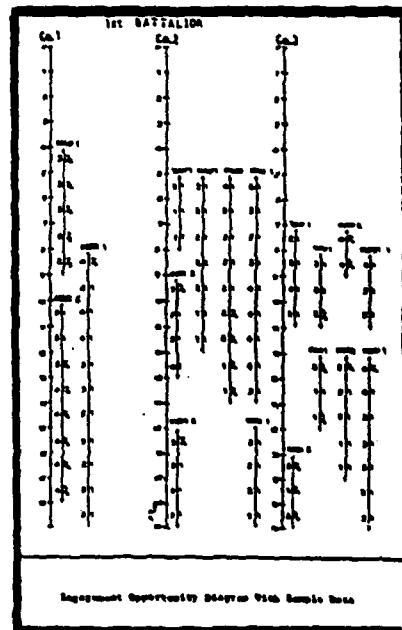
ENGAGEMENT OPPORTUNITY STATISTICS
(AT TIME HISTORY OF ARMOR/ANTIARMOR
WEAPON INTERVISIBILITY

KILL RATE ANALYSIS

The basic kill rate equation for direct fire weapons is shown on the accompanying chart. It is basically the Lanchester differential expression, and is integrated minute-by-minute during the dynamic combat analysis. There is a separate kill rate equation, or set of range-dependent equations, for each major weapon pair.

The kill rates used in the Battle Book method represent best estimates of realistic, tactical kill rates, and as such are products of not only analytical calculations but incorporate experience gained in field experiments that modifies theoretical values. Extensive use of force-on-force data from CDEC field tests as well as British experiments is used.

In addition to range dependent fire kill rates, estimates of defender kills due to attacker force artillery are used. These are calculated directly from known or suspected tube numbers and firing doctrine.

KILL RATE ANALYSIS

BASIC KILL RATE EQUATION

$$R_K = R_F \times S \times P_K \times T$$

WHERE:

R_K IS THE WEAPON KILL RATE IN KILL/MIN.

R_F IS THE <u>TACTICAL FIRING RATE</u>.

S IS A <u>FIRING RATE SUPPRESSION FACTOR</u> THAT ACCOUNTS FOR
ARTILLERY EFFECTS, SMOKE OBSCURATION, HAZE, ETC.

P_K IS THE <u>PROBABILITY OF TARGET KILL</u> GIVEN A SHOT
(OR BURST)

T IS A <u>TARGET FACTOR</u> THAT DEGRADES THE P_K DUE TO
EFFECTS SUCH AS FIRING AT DEAD TARGETS, NON-PINPOINTED
(SUPPRESSIVE) FIRE, AND IS BASED ON ACTUAL FIELD
EXPERIMENTS.

DYNAMIC COMBAT ANALYSIS

The accompanying chart shows the sequence of inputs and calculations needed for the dynamic combat computations.

A minute-by-minute worksheet is used to calculate red and blue losses and adjust force sizes during that time increment. Using the engagement opportunity chart, the company attack units that can engage various defending antiarmor weapons, and vice versa, are identified. At this point, the analyst has a tactical choice of which units actually engage, if several possibilities exist. The force numbers, ranges, and appropriate kill rates are entered in the left-hand columns, and corresponding (fractional) losses computed. The force strengths are then readjusted for these losses in the right hand column; these force strengths are appropriate for the next minute's calculations. The computation proceeds minute-by-minute until a logical battle conclusion (unacceptable losses on one side, overrun condition, etc.)

The minute-by-minute calculations are summarized on two battle summary sheets (one for RED kills, one for BLUE kills), It shows on the right side, kills per minute, and on the bottom, kills by defending (or attacking) unit. The battle summary charts comprise the major data output of the dynamic combat analysis.

THE DYNAMIC COMBAT ANALYSIS COMPUTES MINUTE-BY-MINUTE
LOSSES ON BOTH SIDES AND SUMMARIZES BATTLE RESULTS
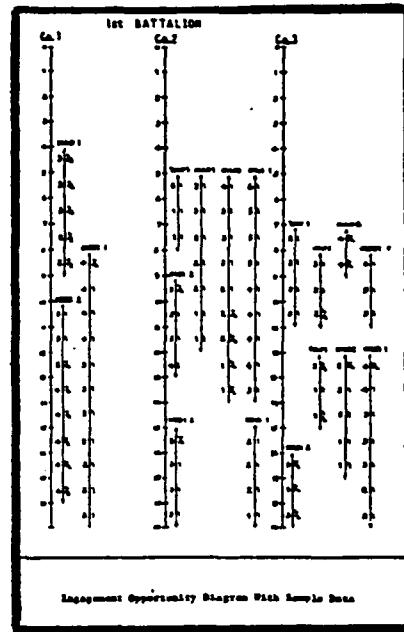
ENGAGEMENT OPPORTUNITY
CHARTS

MINUTE-BY-MINUTE
WORKSHEET
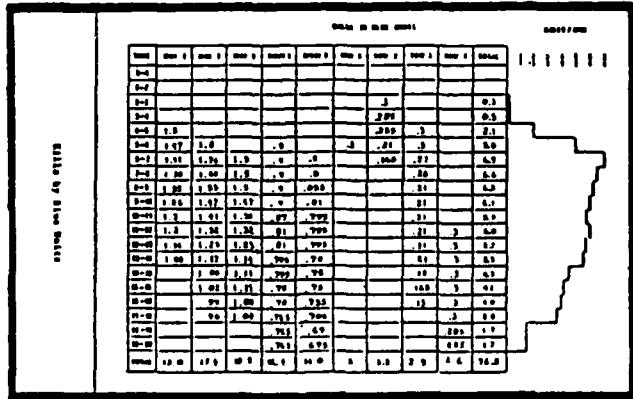
BATTLE SUMMARY SHEETS

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SECTION 2

BATTLE BOOK CALCULUS METHOD

SELECTION OF MAP AND SCALE; OVERLAYS

> Materials have been provided in this document which will permit the
> application of the Battle Book Calculus Method to any one of three
> map scales; however, a 1/25,000 scale seems to be best.

The 1/50,000 scale map is the standard military map and is most readily
available for use with the Battle Book Calculus Method. However, since it
is necessary to do such things as count threat weapons in coverage, the small
scale makes these tasks difficult, though possible.

Copies of a 1/25,000 topographic map are readily available commercially
at stores in German cities and towns which sell stationery. The scale of
these maps is ideal for using the Battle Book Calculus Method. However,
these maps use a different UTM coordinate system and they must be used with
caution. It is, however, an easy matter to plot positions on a 1/50,000
military map and translate them to the 1/25,000 map. The maps contain the
same detail on such things as vegetation, roads, trails, and contain elevation
contour lines.

1/25,000 maps are available from the Defense Mapping Agency for certain
other geographic areas, including Korea.

For greater detail a 1/10,000 map is required. A map to this scale is
not readily available. Two options are available to the Battle Book Calculus
Method user. First it is possible to photographically enlarge a map of a
smaller scale. Secondly, it is possible to construct a simplified map at
the 1/10,000 scale showing only major features of tactical interest. To
construct a map to this scale, simply lay out a grid system on butcher paper
with UTM grid spacing of 4 inches or 10 cms. Then, trace in, by referring to
a smaller scale map, the principal factors of interest such as major contour
lines, wooded areas, roads, trails, and uban areas.

For the battle planning in the contact zone, a clear sheet of acetate
is layed over the map. Normally, the acetate should be large enough to
cover all of the direct fire zone ($\sim$4 km in depth) plus margins to show
artillery patterns. The acetate should be marked with grid coordinate
intersections to facilitate alignment on the map.

Analyst with 1/50,000 Scale Map
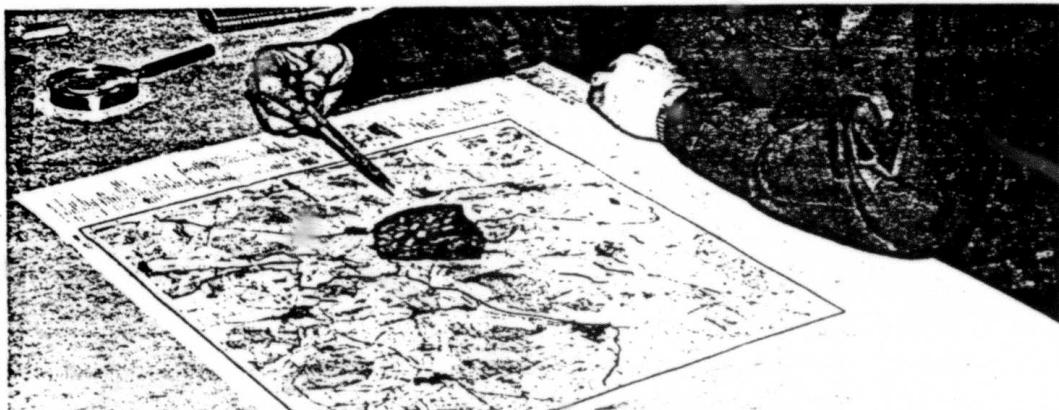
Analyst with 1/25,000 Scale Map
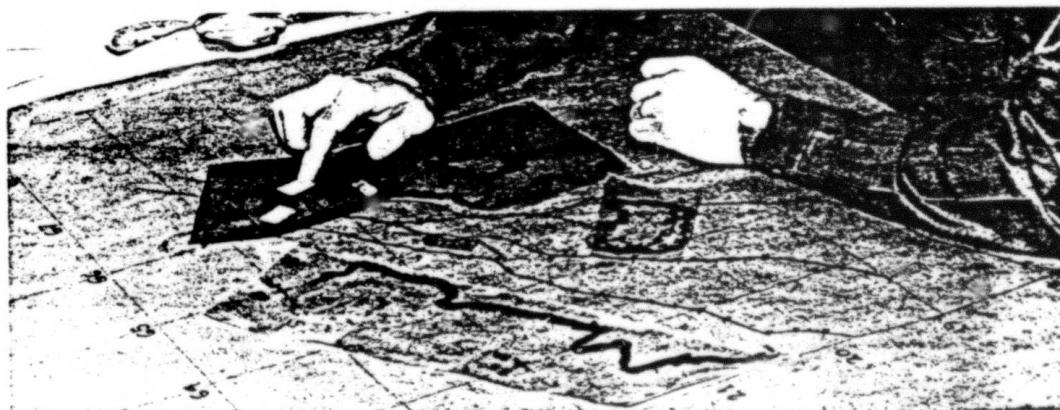
Analyst with 1/10,000 Scale Map

ORDER OF BATTLE

> The Battle Book Calculus method requires a detailed description
> of the order of battle.

Documentation needed to formulate detailed battle plans should include
the following:

1. Mission Statement

    Statement of mission

    Map (1/50,000) showing sector boundaries, adjacent sectors, force
    deployment in standard military symbols, and major axes of threat
    advance.

2. Task Organization

    Identify units and add detail to include numbers of weapons by
    unit and other major equipment items.

3. Threat

    Identify threat by type unit and principal axes of advance into
    sector. Add detail to include numbers of principal fighting vehicles
    and support from artillery, air defense, and tactical air.

4. Concept of the Battle*

    A description of expected combat action in the battalion task
    force sector. This includes: a description of Red maneuver plans
    and objectives. Blue plans for maneuver of forces, expected
    engagements, and anticipated exchange of losses, and discussion of
    use of supporting artillery, attack helicopters, and tactical air.

5. Coordination Plans

    Details for occupation and withdrawal of positions, recognition
    cues for passage through friendly units, and contact points in
    assigned zones in MBA.

    Description of plans to withdraw forces, routes, and reorganization
    or units and occupation of assigned position in MBA.

6. Command and Communications Plan

    Describe plan, show location of command posts, list essential
    equipment and show diagram for communications network (including
    procedures for outages).

7. Supporting Maps and Map Overlays

    This section should indicate a number of maps and overlays which
    provide details of the terrain, the Red Attack, and Blue plans.
    Among the maps and overlays which should be included in this
    section are the following:

---

* This description may be modified as insights are developed after conducting
  the battle analysis described in subsequent sections.

A. Maps

Special relief maps and other maps reflecting the character of the terrain in formats different from the standard 1/50,000 map.

1/25,000 and 1/10,000 maps (if available) of the direct fire zone.

B. Map Overlays

- Details of defensive positions and of detailed attack routes.

- Details of Blue unit maneuver routes in moving from initial positions to alternative positions and withdrawal routes to MBA.

- Attack helicopter FAARP, approach routes, and firing positions in support of ground units.

- Red artillery locations and artillery fans.

- Blue artillery locations and fans.

- Barrier plan.

8. Artillery Fire Support Plan

Show details of artillery plan by target number, location, type/caliber of weapon, number and type of rounds fired. Show fire support communications net.

9. Attack Helicopter Fire Support Plan

Show details of attack helicopter operations by FAARP location, nap-of-earth routes, forward holding positions, and pop-up firing positions. Include details of timing of arrival, duration of support, and number of sorties.

10. Barrier Plan

Description of barrier plan by barrier number, location, and description.

11. Service Support

Location of trains and vehicle collecting points and logistical networks.

12. Other Plans

STRUCTURING THE DEFENSE FORCE

> The number and location of the defense units is determined and plotted on the map.

The defensive weapons will normally be in static firing sites. Depending on the degree of resolution needed in the analysis and the actual disposition of units, weapons may be treated individually or in groups.

Often, defense weapons will be closely grouped in platoons or sections and composed of only one weapon type with, perhaps a 25M spacing. In this case, it is not necessary to plot each weapon site. Plot only the position of each such unit on the map with the unit designation. The point selected for the defensive unit should be considered to be the center of mass of the unit.

If a single weapon is deployed alone, or weapons in a unit spaced or oriented such that they have substantially different fields of view, the weapon(s) should be identified as separate positions.

Eight (8) digit UTM grid coordinates should be identified for each firing site.

An example of a defense force structure is given below:

UNIT DESIGNATION	MAP DESIGNATION	WEAPON TYPE	NUMBER OF WEAPONS	UTM COORDINATES
1st Platoon, Troop A, 1/11	①	M551	6	8521 5625
1st Platoon, D Company, 1/11	△1	M60A3	5	8432 5412
Tank 1, 2nd Platoon D Company, 1/11	△2	M60A3	1	8316 5110
Dragon Squad, Troop A, 1/11	[A]	DRAGON	3	8114 5231

The defensive sites should be plotted and identified on the acetate overlay at the correct map coordinates.

Analyst Plotting Defense Positions

WEAPON COVERAGE TEMPLATE

> Weapon Coverage Templates that show intervisibility with the
> terrain are constructed from acetate for each defense weapon site.

Intervisibility between attacking and defending elements is required for direct fire engagement between opposing forces to occur. Therefore, it is necessary to determine the effects of terrain cn intervisibility of each unit of the opposing forces. In Battle Book Calculus methodology, the intervisibility for each defensive site is displayed on an acetate coverage diagram overlay. The diagram must be of the same scale as the map and indicate the maximum range of the weapon, and the other range zones used. A coordinate mark will help to orient the overlay properly on the map.

Construction of the weapon coverage template is shown on the accompanying figure. First, a basic template showing maximum range and dead zone, if any, for the weapon type is obtained. Masters and acetate templates for some weapons coverage are provided in the back of this document. They are provided for each of the three scales: 1/50,000, 1/25,000, and 1/10,000. An example is shown here. A maximum weapon range is shown, as well as the 400 meter range. A 120° arc of coverage is illustrated; however, this may be varied as required. Next, range zones of interest (see Appendix A for further explanation of choice of range zones) are marked on the template.

Finally, the regions on the map which are intervisible from the site are determined. The shaded areas are regions for which intervisibility with the weapon position does not exist. Intervisiblity may be determined in a variety of ways:

(1) A computer code utilizing digitzed terrain data;

(2) Analysis of the contour lines on a topographic map; and

(3) Observation from the actual weapon site in the field.

Grid square indices are used to orient the coverage diagram properly on the map.

STEP 1

Basic Weapon Template shows
maximum and minimum ranges,
field of view for each
weapon type.
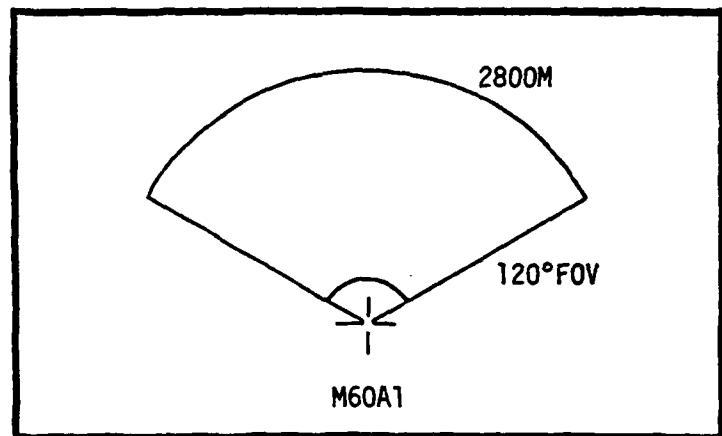
STEP 2

Range Zones are marked on
template.
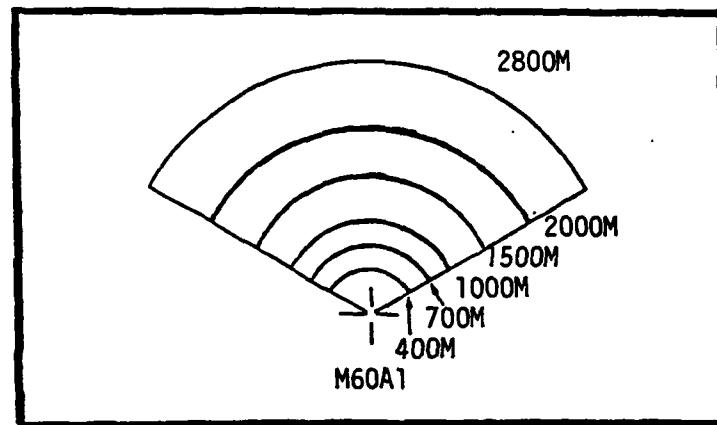
STEP 3

Regions of intervisibility
are determined for a
particular weapon site.
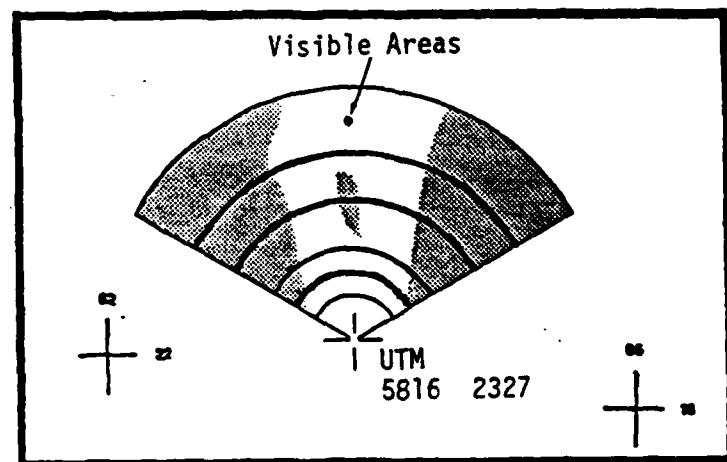
CONSTRUCTION OF COVERAGE DIAGRAMS

STRUCTURING THE RED FORCE

> The Red force may consist of T62 or other tanks and BMP infantry carriers in specific formations.

The attack formation of the Red force must be laid out to the map scale. Scale drawings of typical company formations are shown here and additional master sheets are contained at the back of this document.

A typical enemy force might be a Tank Regiment, which consists of weapons as shown below.

For primarily armor/antiarmor battles, the only threat weapons considered are tanks and Sagger-equipped BMP infantry combat vehicles. Shown here are template patterns for tank and mechanized infantry units in three scales.

For each Red company select a formation. Make an acetate template of the tank company with marker pen for the appropriate map scale you have selected. Using double back tape, tape this template to a piece of think cardboard and place double back tape on the bottom of the template. Mark the template with the appropriate company designation. Colored marker pen may be used to identify the company with its parent battalion.

UNIT	NUMBER OF T-62 WEAPONS
A Company 1st Batt	10
B Company 1st Battalion	10
C Company 1st Battalion	10
D Company 2nd Battalion	10
E Company 2nd Battalion	10
F Company 2nd Battalion	10
G Company 3rd Battalion	10
H Company 3rd Battalion	10
I Company 3rd Battalion	10

Typical Red Force Structure

LINE	COLUMN PLATOONS	WEDGE ONE UP

1/10,000

1/25,000

1/50,000
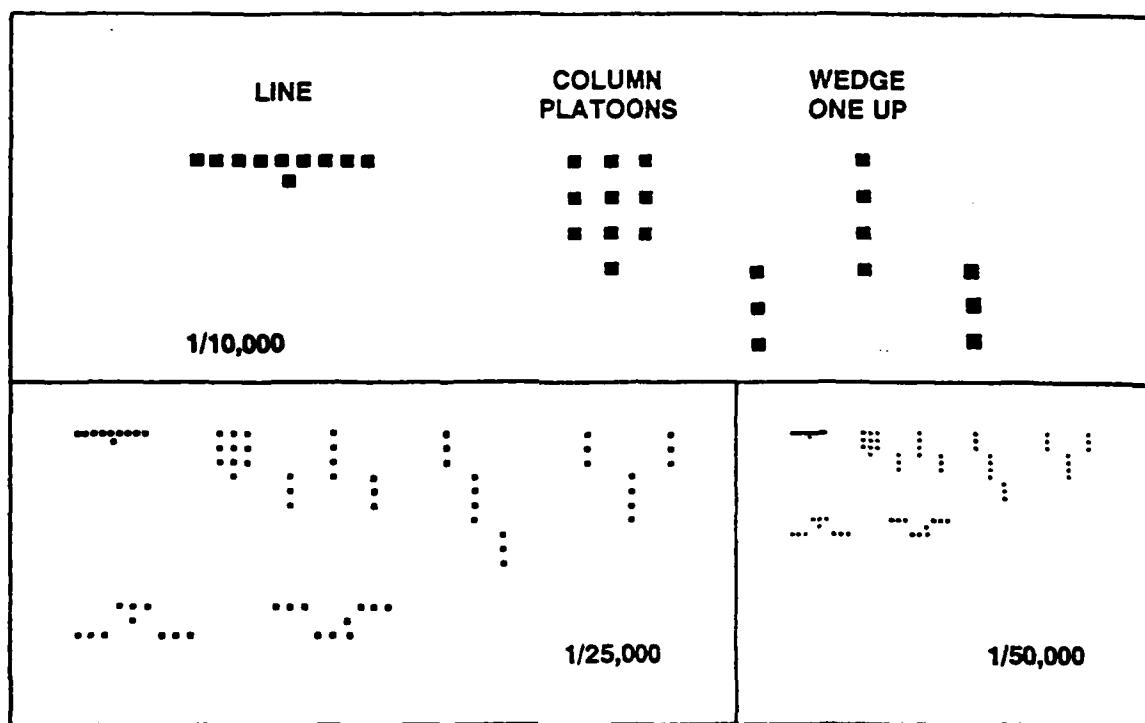
Typical Red Formations
(Complete Set Contained in Back of Document)
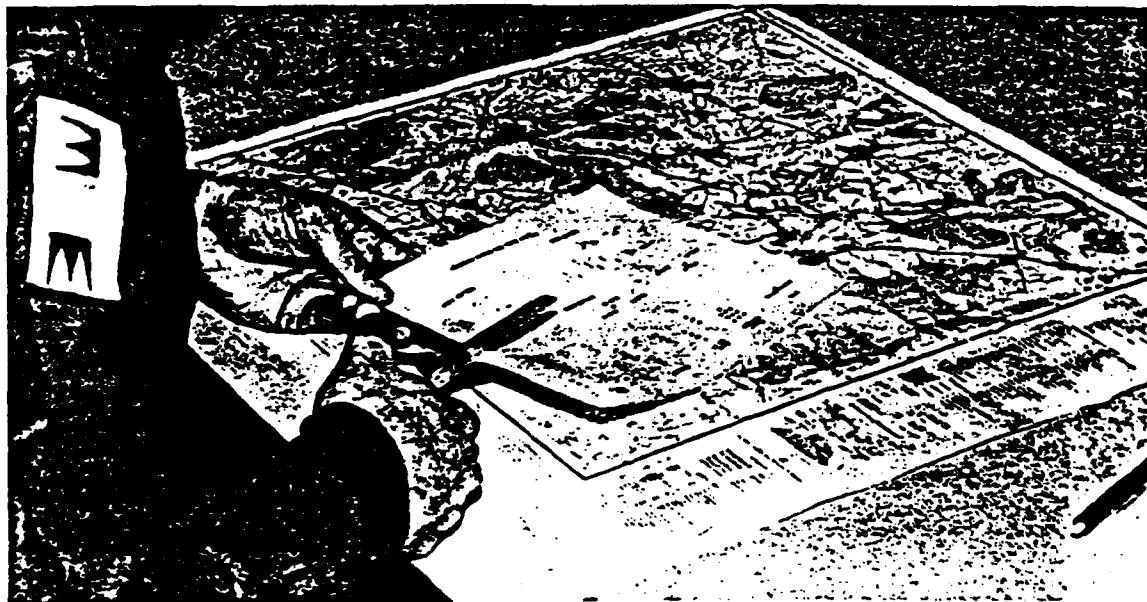
Analyst Preparing Red Company Templates

PLOTTING DETAILED ATTACK ROUTES

> Routes of advance of Red units and Blue withdrawal routes are
> plotted and time tagged at one minute intervals.

Plot on the acetate overlay the routes of advance for each company-
sized unit of the Red force. Blue withdrawal routes should be similarly
plotted. These must then be time tagged in one minute intervals. A scale
for doing this is shown here and an additional copy is provided at the
back of this document. Use the scale and construct an acetate template for
the appropriate map scale and speed.

Time scales for three map scales (1/10,000; 1/25,000; and 1/50,000) are
given for two speeds (12 kilometers per hour, and 18 kilometers per hour).
Time scales for other speeds may be constructed as required. In the
example which is given later, 12 kpm has been used for the speed of the Red
attacking force.
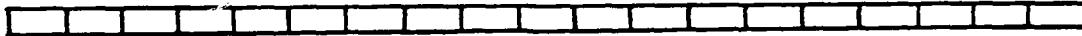
1-MINUTE INCREMENT   200 METER   12 KPH - 1:25000

Rate of Movement Scale
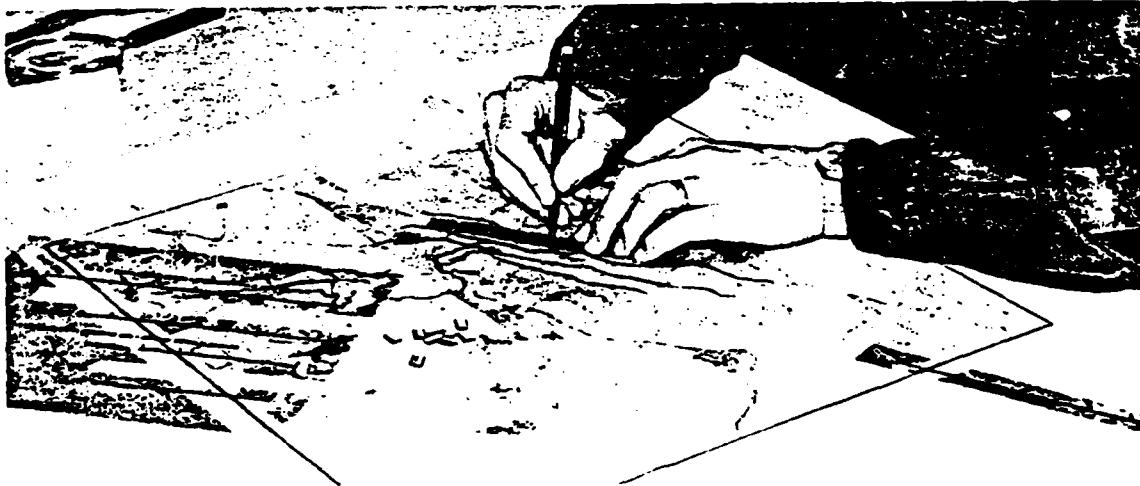
Analyst Using Rate of Movement Scale

The figure below shows a completed acetate overlay. The defensive weapon positions and nine attack routes of advance are shown: one for each company (10 tanks) of each of the three battalions of an enemy regiment. One-minute time interval marks are placed on each route to indicate the rate of advance of attacking weapons. The attack advanced at 12km/hr or 200 meters/min. Variable speeds may be used for different routes or different parts of a route, at the judgment of the analyst.

The acetate should be removed from the map and duplicated to provide a simple black and white copy showing only the attack routes with friendly weapon positions and eliminating the background clutter of the map. This route map is then used to determine individual weapon engagement opportunities for both attacking and defending weapons.
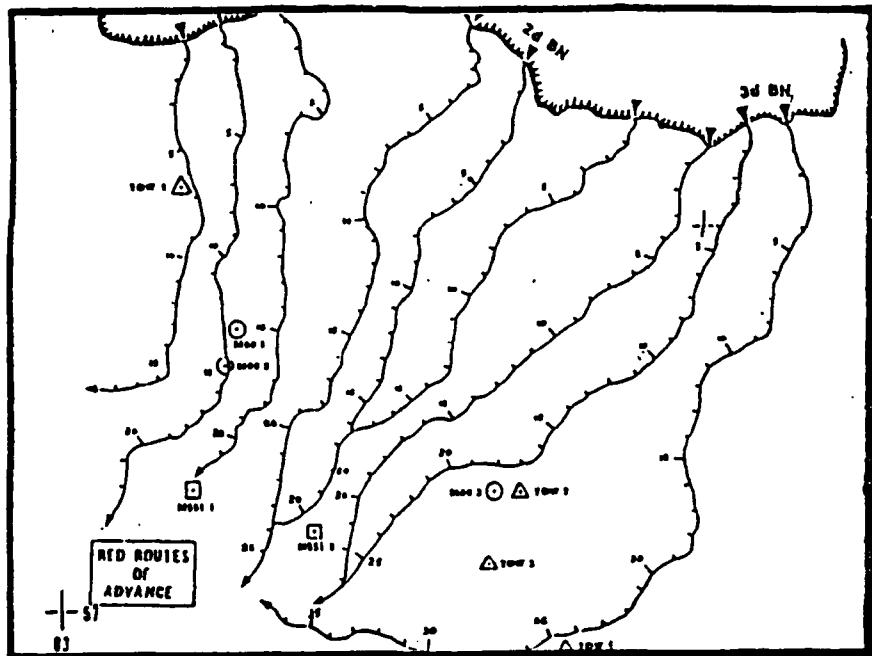
DETERMINATION OF ATTACK/DEFENDER INTERVISIBILITY

> Combining the battle plan acetate overlay with the coverage
> diagram shows attack/defender intervisibility.

The figure opposite depicts the acetate intervisibility template
positioned on the route map. This shows directly those times and the range
zones for each route for which intervisibility exists. At the same time,
the exposure of the advancing enemy unit may be estimated. Exposure is
defined as the fraction of the enemy unit which, due to intervisibility
effects, can be seen by the friendly weapon position. Thus, at a time
when the enemy route is fully in the clear, the exposure is unity. When
the enemy route runs close to a non-intervisible area, the exposure may be
0.5 or some other value less than unity. Exact determinations of exposure
require the use of scale templates of the attacking unit formation, but for
most analysis an estimate by the analyzers will be more convenient and
provide sufficient accuracy. Estimating exposure is important in that it
does not permit all live tanks of an enemy unit to fire on a friendly position
when in fact only some fraction would be expected to have a line of sight
with it. The time of intervisibility, range zone, and exposure data, determined
using the technique shown opposite are recorded for each defensive weapon
position. To do this in a form convenient for analysis, a rectified and
time-aligned route map is used.

On the following page is an example of a rectified and time-aligned
route map, referred to as an Engagement Opportunity Diagram (EOD). This
is a route map in which all routes are redrawn as straight parallel lines
and the time marks all aligned horizontally. The figure shows this for the
first battalion of the attacking regiment.

On the subsequent page is shown the completed EOD with the time, range
zone, and exposure data determined for each defensive weapon position. To
the right of each route, a double-headed arrow is drawn to indicate the time
intervals during which intervisibility exists for a given friendly weapon
position. The double-headed arrow is labeled at its top with identification
of the friendly position. To the right of the double-headed arrow, the
estimated exposure is written for each time interval and to the left, the
range zone. As an example, the coverage diagram/overlay shows that for the
M551 Position 2 against Route 1, intervisibility starts with the 10th minute,
in ranges Zone 5, at an estimated exposure of 1. Thus, on the EOD, the
double-headed arrow for M551 Position 2 starts at time 10 minutes, with a
1 to the right and a 5 to the left.

For Route 2, the overlay indicates intervisibility beginning at about
9 minutes, in Zone 5, with an estimate exposure of 0.5, since to the east of
the track lies an area of no intervisibility. These observations are reflected
on the EOD, next to Route 2. Note that the coverage of Route 2 for Position
2 is interrupted from time 13 to 15 by a non-intervisible area on the map.
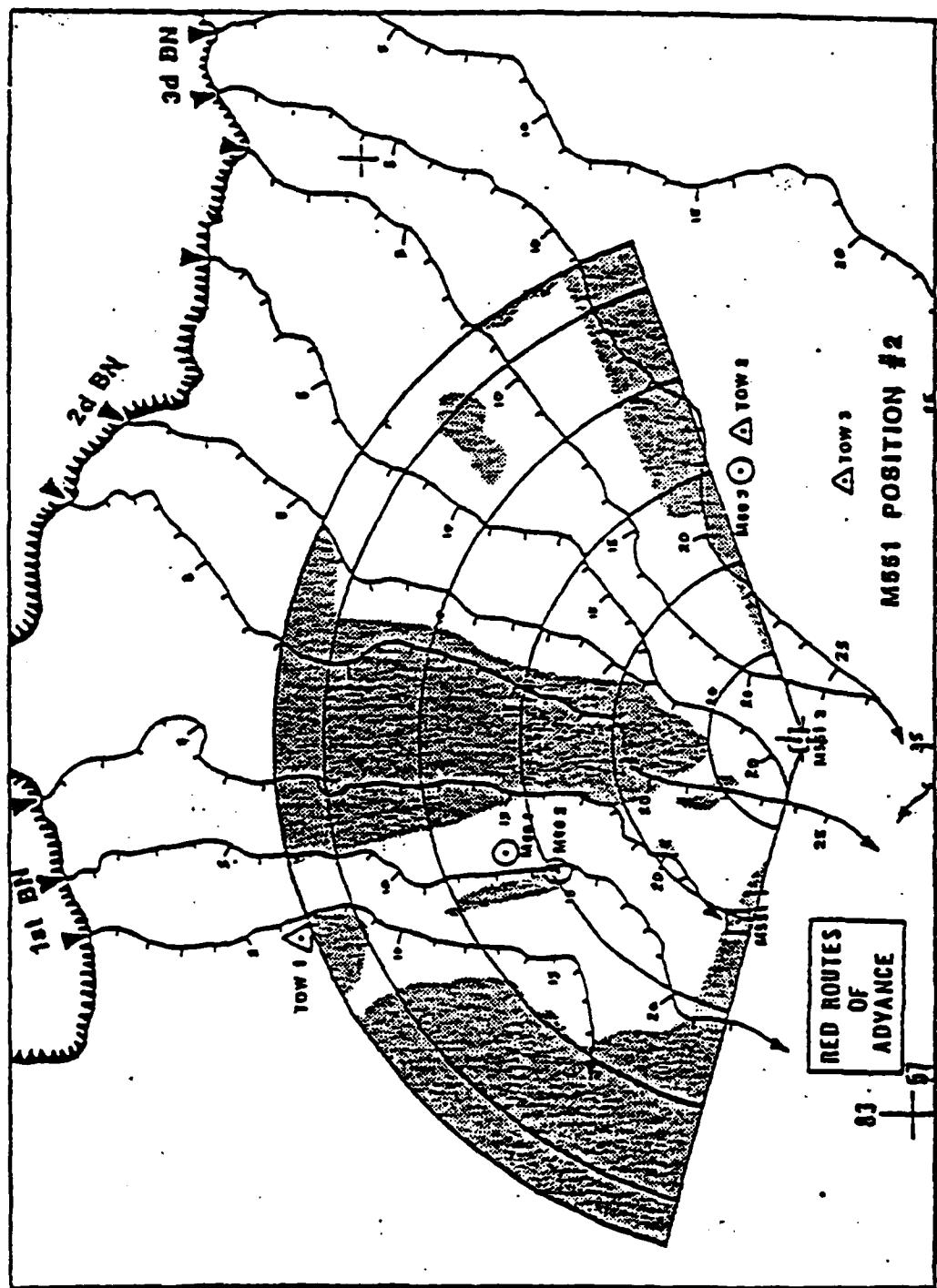
Intervisibility Template Overlaid on Attack Routes

1st BATTALION

Co.1	Co.2	Co.3
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19

Rectified and Time-Aligned Route Map
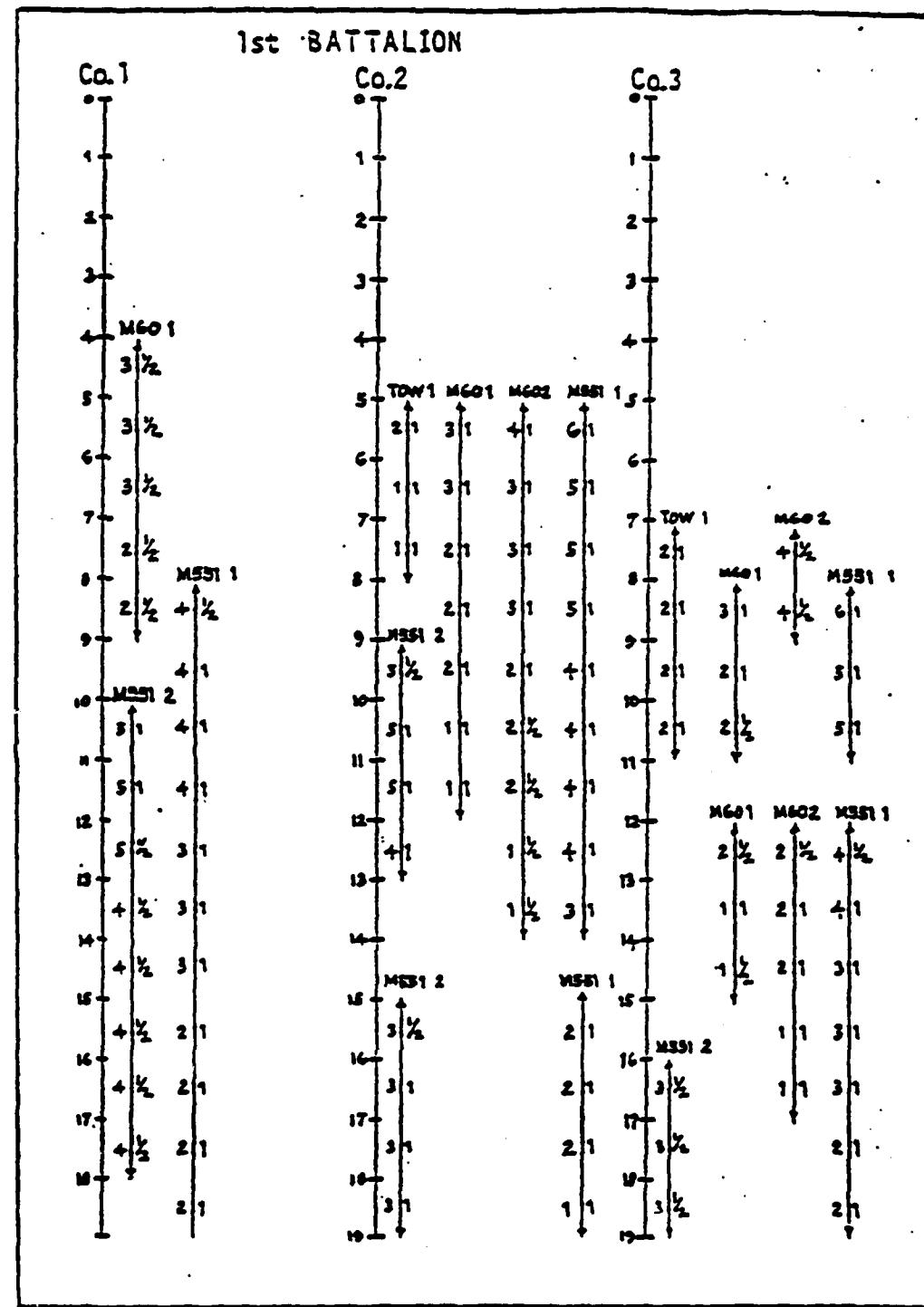
Engagement Opportunity Diagram With Sample Data

KILL RATE ANALYSIS

> Battle Book Calculus requires the use of range-dependent, weapon-by-weapon kill rates.

Losses are calculated on a minute-by-minute basis, using the rate of kill of the weapons engaged. This assures that the effective force ratios are based on the weapons actually engaged and are varied as these ratios vary during the battle. For example, if 10 M60A1 tanks are engaging 40 T-62 tanks, all within a firing range of 2,200 meters, the kills during one minute of battle are calculated as shown below.

M60 Kill Rate

10M60s X 0.3 kills/min/tank X 1.0 min = 3 kills of T62 tanks

T62 Kill Rate

40 T62s X 0.02 kills/min/tank X 1.0 min = 0.8 kills of M60 tanks

---

The basic kill rate equation for direct fire weapons is shown on the accompanying chart. It is basically the Lanchester differential expression, and is integrated minute-by-minute during the dynamic combat analysis. There is a separate kill rate equation, or set of range-dependent equations, for each major weapon pair, as illustrated below the equation.

The kill rates used in the Battle Book method represent best estimates of realistic, tactical kill rates, and as such are products of not only analytical calculations but incorporate experience gained in field experiment that modifies theoretical values. Extensive use of force-on-force data from CDEC field trials as well as British experiments is used.

Appendix A gives details for calculating Battle Book kill rates.

BASIC KILL RATE EQUATION

$$R_K = R_F \times S \times P_K \times T$$

WHERE:

R_K IS THE WEAPON KILL RATE IN KILLS/MIN.

R_F IS THE <u>TACTICAL FIRING RATE</u>.

S   IS A <u>FIRING RATE SUPPRESSION FACTOR</u> THAT ACCOUNTS FOR
ARTILLERY EFFECTS, SMOKE OBSCURATION, HAZE, ETC.

P_K IS THE <u>PROBABILITY OF TARGET KILL</u> GIVEN A SHOT (OR BURST).

T   IS A <u>TARGET FACTOR</u> THAT DEGRADES THE P_K DUE TO EFFECTS SUCH
AS FIRING AT DEAD TARGETS, NON-PINPOINTED (SUPPRESSIVE)
FIRE, AND IS BASED ON ACTUAL FIELD EXPERIMENTS.

SAMPLE KILL RATE TABLE

M60A1 Firing At Advancing T-62

RANGE ZONE	RANGE BAND	R_f	S	P_k	T	KILL RATE (KILLS/MIN)
1	400 - 700	1.5	.95	.3	.75	.3
2	700 - 1000	1.0	.95	.18	.75	.12
3	1000 - 1500	0.5	.95	.11	.75	.04

KILL RATES AND EFFECTS OF ARTILLERY

> The use of artillery, especially by red, inflict losses and
> suppression.

In addition to kills from direct fire, blue losses may be anticipated
due to red indirect fire. The suppressive effects of HE or smoke barrages
act to reduce blue firing kill rates. This effect is accounted for in the
"S" factor of the kill rate equation.

Two types of artillery fire must be considered:

(1) Unobserved fire

(2) Observed, and therefore adjusted, fire.

Both types of indirect fire delivery can cause actual losses and
suppression. Appendix B discusses kills due to artillery fire of various
intensities, and derives examples of typical kill rates which are shown
opposite. The suppression factor "S" is discussed in Appendix A.

SAMPLE ARTILLERY KILL RATES

DEFENDING ELEMENTARY TARGET	122MM HOWITZER		152MM HOWITZER	
	SINGLE BATTERY SHELLING	TWO BATTERIES SHELLING	SINGLE BATTERY SHELLING	TWO BATTERIES SHELLING
Tow Bunker	.0019	.0035	.0010	.0018
Foxhole	.0035	.0059	.0022	.0040
Tank	.0044	.0071	.0022	.0040
APC	.0052	.0081	.0026	.0047

Artillery Kill Rates/Minute for a One Hour
Bombardment at 2/3 Maximum Range

DYNAMIC COMBAT ANALYSIS - MINUTE-BY-MINUTE ENGAGEMENTS

> Loss Exchanges are computed minute-by-minute using the Engagement
> Opportunity Diagram (EOD) and Kill Rate Tables.

The figure opposite shows a typical form used to conduct the engagement analysis. This form may be duplicated to provide a copy for each minute of battle. The form shown is for the time interval between 5 and 6 minutes. The engagement assessment of this time interval is conducted in conjunction with the EOD and the worksheet completed for the preceding time interval. Thus, the figure shows that M60 Position 1 can engage the 1st company of the 1st battalion (Route 1) or the 2nd company of the 1st battalion (Route 2) both in range Zone 3. Tactical judgment must be used to decide. In the example, M60 Position 1 was assigned to the 1st of 1st although the analyst might have been chosen the other possibility. This is the same choice the commander in the field must make.

The kill rates (K.R.) from the previously derived tables are entered into the appropriate columns. The kill rate used must correspond to the proper range zone.

For an M60 the K.R. is 0.3 and is entered. The strength of M60 Position 1, as taken from the worksheet for the time interval 4 to 5 minutes, is 4.9 tanks. The product of these numbers, 1.47, is entered in the loss column and is charged against the 1st company of the 1st battalion. This is repeated for each of the friendly units, consulting the EOD. Note that the EOD has indicated that M60 Position 1, M551 Position 2, and TOW 4 have no engagement opportunities between time 5 to 6 and, accordingly they can neither engage or be engaged and attrited in this time interval. The EOD shows that TOW 1 has only one engagement opportunity, namely against the 2nd of the 1st, and no judgment is required regarding fire distribution.

For the Red on Blue engagements, a Red unit may engage any Blue position which is firing and with which it has intervisibility. Again, tactical decisions may be required, as indeed they would be in the field. For example, on the worksheet, the 3rd of the 2nd is firing on TOW 2. This is possible since the complete EOD, showing all nine routes, shows that intervisibility does exist and TOW 2 is firing, although not at the 3rd company of the 2nd battalion.

After the engagements and losses have been determined, the Force Adjustments portion of the worksheet is completed. Thus for M60 Position 1 the strength at time 5 (from the previous worksheet, time 4 to 5) was 4.9 tanks. This is entered under the "initial strength" column. Inspection of the Red on Blue engagements and losses shows Mto Position 1 lost .085 to the 1st of 1st and 0.1 to the 2nd of 2nd, for a total loss of .185. This is entered in the loss column. The final strength (strength at time 6) is therfore 4.9 - .185 = 4.7. Note that strengths are rounded to the nearest tenth. The final strengths calculated for one time interval become the initial strengths for the next.

TIME 5 to 6

ENGAGEMENTS		LOSSES			FORCE ADJUSTMENTS			
BLUE ON RED	ZONE	K.L	STRENGTH	LOSS	BLUE EXIT	INITIAL STRENGTH	LOSS	FINAL STRENGTH
MGO 1 —1/1	/	.3 *	4.9	* 1.47	MGO 1: 4.9	- .185	= 4.7
MGO 2 —2/1		.3 *	6	* 1.8	MGO 2: 6	- .2	= 5.8
MGO 3 —		*		*	MGO 3: 5	-	* 5
MSS1 1 —2/4		.15 *	6	* 0.9	MSS1 1: 6	-	* 6
MSS1 2 —		*		*	MSS1 2: 6	-	* 6
TOW 1 —2/1		.15 *	2	* .3	TOW 1: 2	-	* 2
TOW 2 —2/3		.15 *	1.4	* .21	TOW 2: 1.4	- .3	* 1.1
TOW 3 —1/3		.15 *	2	* ..	TOW 3: 2	- .176	* 1.8
TOW 4 —		*		*	TOW 4: 2	-	* 2
RED ON BLUE				EXP LOSS	RED EXIT			
1/1 —MGO 1		.02 *	8.5	* .5 * .085	1/1: 8.5	- 1.47	* 7.0
2/1 —MGO 2		.02 *	10	* 1 * .2	2/1: 10	- 3	* 7.0
3/1 —		*		* *	3/1: 10	-	* 10
1/2 —		*		* *	1/2: 10	-	* 10
2/2 —MGO 1		.02 *	10	* .5 * .1	2/2: 10	-	* 10
3/2 —TOW 2		.02 *	10	* .5 * .1	3/2: 10	-	* 10
1/3 —TOW 3		.02 *	8.5	* 1 * .176	1/3: 8.5	- .3	* 8.5
2/3 —TOW 2		.02 *	10	* .5 * .1	2/3: 10	- .21	* 9.8
3/3 —TOW 2		.02 *	10	* .5 * .1	3/3: 10	-	* 10

COMMENTS: TOW 1 withdraws due to approach of 1/1

Minute Worksheet With Data, Minutes 5 to 6

DYNAMIC COMBAT ANALYSIS - TIME DISPLAYS

> A running time display of the battle illustrates what is
> happening and helps make tactical decisions.

A running display of Red forces, positions, and strengths is obtained
by using the actual battle plan route map and updating it after each minute
by writing next to the appropriate minute mark the strength of the Red unit
at that time.

The figure opposite shows this update after the calculations for time
interval 5 to 6 have been made. On the basis of this situation map, tactical
decisions may be made. Thus, the close approach of the 1st of the 1st to
TOW 1 produced a decision to withdraw TOW 1. This decision is shown as a
comment at the bottom of the worksheet.

Insights with respect to deployment are directly available. TOW 1
was in the battle for one minute before being withdrawn. It was deployed
too far forward for a long-range weapon. TOW 4, as it turns out, was
deployed too far to the rear, even for a long-range weapon, to get into the
battle until quite late.
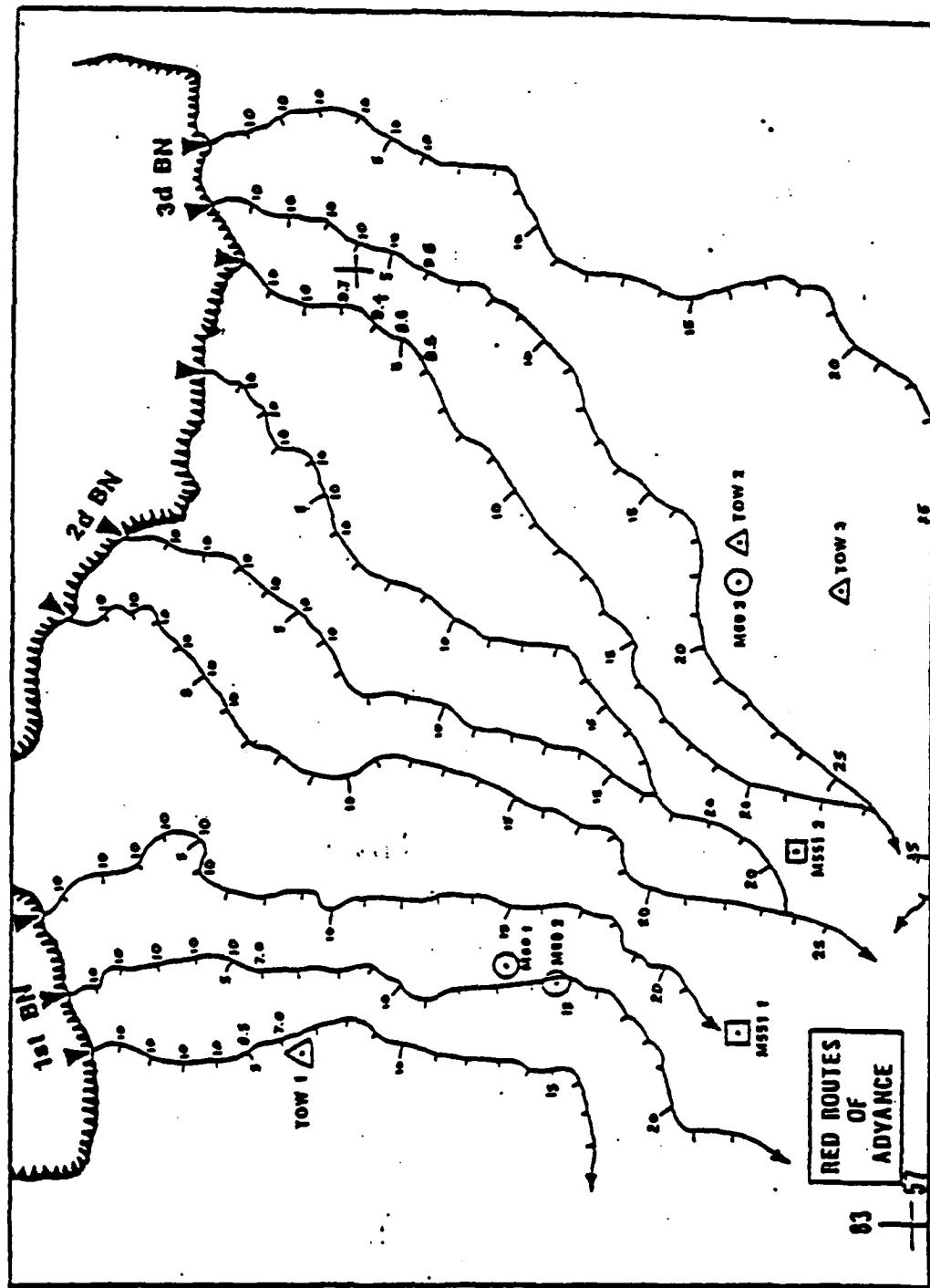
Status of Enemy Forces, Minutes 5 to 6

DYNAMIC COMBAT ANALYSIS - SUMMARY OF RESULTS

> Battle Book results can be summarized in a number of ways to
> evaluate the combat situation.

When worksheets for each time interval have been completed, covering
the time span of interest, summary charts can be prepared, displaying
results concisely and in a form from which insights may be drawn.

The summary chart opposite displays kills by Blue units. Each Blue
unit is listed across the top and time intervals are listed vertically.
The kills by each Blue unit for each time interval are entered from the
worksheets and when these kills are summed horizontally, the total kills
in each time interval are obtained. These can then be graphed as shown to
show how the battle intensity varied with time. The summation of the
kills per time interval column yields the overall total kills.

The minute-by-minute worksheets may easily be modified to keep a
running track of ammunition expenditures. For example, a unit's kills for
a particular minute can be divided by the P_k for the appropriate zone to
compute the number of rounds expended in that minute. Thus, cumulative
rounds fired can be accounted for so that a unit may be removed from battle
when it has expended its basic load.

Other summary data may be completed and presented in tabular or
graphical forms suited to the purpose of the analysis. The method lends
itself readily to adjustments in the minute-by-minute calculations to develop
data needed for special analyses. The method can also be adjusted at any
time during the battle to alter plans based upon the developing character
of the tactical situation. Because the techniques used are largely
tactically natural, military personnel using the method can emphasize the
tactical play without being distracted by mysterious mathematical or
simulation techniques.

KILLS / MIN

KILLS BY BLUE UNITS

TIME	MG 1	MG 2	MG 3	MSSL 1	MSSL 2	TOW 1	TOW 2	TOW 3	TOW 4	TOTAL
0-1										
1-2										0.3
2-3	1.5						.3			0.3
3-4	1.17	1.8					.205			2.1
4-5	1.11	1.74	1.5			.3	.255			5.0
5-6	1.30	1.60	1.5	.9	.9		.21	.3		6.9
6-7	1.35	1.53	1.5	.9	.9		.165	.3		6.6
7-8	1.26	1.17	1.17	.9	.055			.27		6.3
8-9	1.2	1.41	1.36	.9	.01			.20		6.1
9-10	1.2	1.32	1.32	.9	.795			.21		5.9
10-11	1.14	1.23	1.23	.07	.795			.21	.3	6.0
11-12	1.00	1.17	1.14	.01	.795			.21	.3	5.7
12-13		1.06	1.14	.81	.70			.21	.3	5.5
13-14		1.02	1.11	.795	.78			.21	.3	4.3
14-15		.99	1.08	.795	.75			.10	.3	4.1
15-16		.96	1.08	.78	.735			.165	.3	4.0
16-17				.78	.705			.15	.3	3.8
17-18				.765	.69				.205	1.7
18-19				.765	.675				.255	1.7
19-20				.765						
TOTAL	13.0	17.4	15.5	12.4	11.0	.3	1.2	2.9	2.6	76.9

Kills by Blue Units

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APPENDIX A
FACTORS IN THE KILL RATE EXPRESSION

1. **THE KILL RATE EXPRESSION**

The basic kill rate equation used in the Battle Book Calculus method is:

$$R_k = R_f \times S \times P_k \times T \qquad \text{(A-1)}$$

where

R_f is the average tactical firing rate;

S is a suppression factor due to enemy artillery or obscured vision;

P_k is the probability of target kill, given a shot;

T is a kill degradation factor which accounts for engagements against false targets or dead targets.

Desired kill rates must be computed for each defender/attacker weapon pair, using available firing data and lethality data generated by tests or published in the pertinent literature. The purpose of this Appendix is to present a simplified methodology for deriving the required kill rates given the availability of the appropriate input data.

Two important criteria must be kept in mind when deriving kill rates:

(1) The average kill rates must be such that the _ratios_ are reasonable. The kill rate ratio goes as the _square_ of a balanced attacker-to-defender ratio. Thus, if a defending tank unit is to have an even battle against an attacking force of 4 times its strength, its kill rate must be 16 times that of the attacker.

(2) The kill rates of both attacker and defender must be such that the battle progresses at a reasonable speed. If kill rates on both sides are too high (even though the ratios may be OK), the simulation ends too quickly, with many highly lethal engagement at long range.

The kill rates presented for reference purposes in this Appendix
are derived in part from observations of field experiments, and as such,
represent values that appear to be reasonable in terms of both kill rate
ratios and pace of battle.

2. RANGE DEPENDENCY

Battle Book II incorporates range dependency into the kill rate ex-
pressions. There are at least three range dependent factors, as illus-
trated in Figure A-1. Of the three, the probability of kill given a shot
is probably the biggest effect, at least for gun systems, and is usually
used to determine range zones. The range dependency of each effect is
discussed in subsequent sections.

RANGE DEPENDENCY OCCURS IN SEVERAL KILL RATE PARAMETERS

- **PROBABILITY OF KILL GIVEN A SHOT** — $P_{K_{SS}}$ vs RANGE
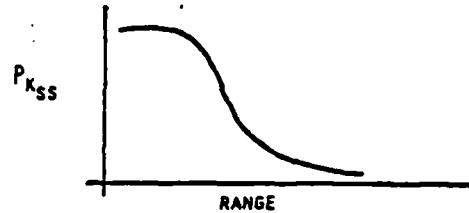
- **FIRING RATES**
  - RED WEAPONS
  - BLUE WEAPONS

  RED ROUNDS FIRED PER MINUTE vs RANGE

- **FALSE AND "PINPOINTED" TARGET FACTOR** — % FIRINGS AGAINST REAL, LIVE TARGETS vs RANGE
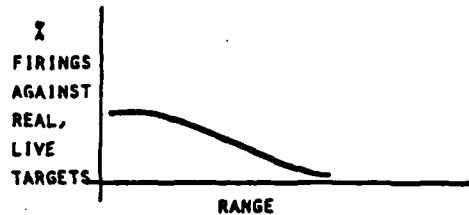
Figure A-1

3. TACTICAL FIRING RATE

Tactical firing rates vary widely with the scenario, type of weapon and firing doctrine. In general, it may be reasonably expected to be range dependent for some weapons. It includes the time to search for, acquire, and lay on a target as well as the cyclic firing rate of the weapon itself. The data presented in this section is intended only as a guide to the commander or analyst, who may wish to modify rates according to the scenario or doctrine at hand.

Two methods have been successfully used to date to calculate Battle Book tactical firing rates: empirical calculations, using systems data combined with doctrine and tactical judgment; and actual field experiment data.

a) Calculated Firing Rates

To calculate tactical firing rates, a firing cycle consisting of the following events may be considered:

(1) Search for and descriminate target.

(2) Acquire target (including lay time).

(3) Fire "n" rounds at a specified (usually maximum) rate.

(4) Move to a new firing site to avoid being pinpointed as a target for direct or indirect fire.

The tactical firing rate is the number of rounds "n" divided by the total cycle time. In a target-rich environment, event 1 may be very short. The number "n" as well as the time for events 1 and 2 may be range dependent. Example A-1 demonstrates a sample calculation for tactical firing rates.

b) Field Experiment Data

A recent study has analyzed tactical firing rates that occur in real time, two-sided field experiments conducted by both U.S. and British teams. A summary of these observed range-averaged firing rates is shown in Figure A-2. These rates are derived from the average number of times the weapon fires, regardless of whether it is fired at a real target or not. The tank firing rates show a wide variation due to doctrine and especially training.

EXAMPLE A-1

CALCULATION OF TACTICAL FIRING RATE

PROBLEM:

An M60A1 tank has 3 alternate defiladed long range field-of-view firing sites on a hill overlooking the Grusselbach River Valley. What is an estimated tactical firing rate for this tank, if it must change sites frequently to avoid being acquired and engaged by attacking ATGM'S. Consider a target rich environment, with lead units approaching 1000m from the defense line.

SOLUTION:

In a target rich environment in good visibility, the acquisition time should be about 15 seconds. The M60A1 can traverse, load, lay, range, and fire the first round in about 20 seconds. Firing can continue for about 1 minute (4 rounds total) before movement to an alternate site is advisable. Movement time to back out, travel, and reposition, is estimated (by the Battle Book user) to be 2 minutes. Thus, the total cycle time is 215 seconds (3.58 min). The tactical firing rate is thus (4 rounds/3.58 min) = 1.12 rounds/minute. This compares favorably with tactical firing rates observed in real-time two-sided field trials (see Figure A-2).

In addition to range-averaged firing rates, the referenced analysis suggested a range dependency to both defending and attacking tank firing rates, as well as attacking ATGM firing rates. The results are interwoven, however, by instrumentation and terrain effects, and complications that accompany the close-in battle. The results in Figure A-3 represent observed relative range-dependent firing rate effects, and should be interpreted and used with caution. The defending ATGM systems (both TOW and Shillelegh) do not show an appreciable range dependency.

c. Sample Tactical Firing Rates

For purposes of guidance in using Battle Book II, experience has shown that the range-dependent firing rates given in Table A-4 give both reasonable kill rate ratios and progress of the battle for contemporary weapon systems and tactics.

Figure A-2. Estimated Relative Firing Rates from Field Test Data

Range Zone	Defending Tank	Attacking Tank	Defending ATGM (Including Shillelegh)	Attacking ATGM
400-700	1.3	(0.7)*	1.0	1.4
700-1000	1.0	1.0	1.0	1.0
1000-1500	0.7	0.5	1.0	0.75
1500-2000	0.4	0.2	1.0	0.4
2000-2500	<0.1	--	1.0	0.3
2500+				

	TACTICAL FIRING RATE (RD/MIN)
DEFENDING TANK (M60A1 or EQUIVALENT)	0.5 - 2.0
DEFENDING TANK (SHILLELAGH)	0.6
ATTACKING TANK	0.1 - 0.5 *
DEFENDING ANTITANK GUIDED MISSILE (TOW or EQUIVALENT)	0.7 - 1.0
ATTACKING AT6M	0.3 - 0.5

* Higher When Firing-on-the-Move.

FIGURE A-3. TYPICAL TACTICAL FIRING RATES OBSERVED IN FIELD EXPERIMENTS

Figure A-4. Sample Range Dependent Tactical Firing Rates, Rounds/min

System	RANGE, m				
	400-700	700-1000	1000-1500	1500-2000	2000-2500
Defending Tank (M60A1 type)	1.5-1.8	1.5-0.8	1.5-0.6	1.5-0.7	0.2-0.5
Defending Tank (Shillelagh missile)	0.6	0.6	0.6	0.6	0.6
Defending ATGM (TOW)	0.7-0.8	0.7-0.8	0.7-0.8	0.7-0.8	0.7-0.8
Attacking Tank	0.6	0.5-0.3	0.4-0.2	0.2	--
Attacking ATGM*	0.5	0.35	0.35	0.2	0.15

*actual number of firings limited by on-board load

4.   SUPPRESSION FACTOR

The suppression factor S degrades the tactical firing rate due to conditions on the battlefield such as haze, dust, smoke, or artillery fire (producing fragments). Two separate cases that contribute to a measurable "S" factor are: obscuration of the optical path which has a characteristic time long compared to the weapon acquisition and firing time; and, suppression of the firing weapon with a characteristic time comparable to or shorter than the weapon acquisition and firing time. The Battle Book Calculus will treat the latter suppression in relatively accurate detail; the "long" term obscuration is described in a subjective manner.

a)   Short Duration Suppression

The suppression factor S as represented in Eqn A-1 represents the fraction of targets or firepower unsuppressed during an artillery bombardment.

Suppression fires confuse, hinder and prevent the defenders from performing their military tasks, and are a by-product of any artillery bombardment. Suppression effects are from (1) obscuration due to dust, smoke or debris, (2) concussion due to blast, (3) the threat of casualties from fragments generated by exploding HE/fragmentation rounds. These effects can be obtained from near misses whereas hits in the lethal area of the target are required for target kill.

The duration of suppression will depend on the mechanism employed. Fragmentation and blast are very temporary effects while obscuration due to dust and smoke from exploding HE rounds can linger for minutes, depending on wind conditions.

The formulas presented in this section do not attempt to deal with the obscuration generated by a possible build-up of smoke, dust or carbon over time. This is a more complicated problem whose solution is a function of cloud density, sensor wave length (i.e., optical, IR, thermal imaging), particle size, weather, and other parameters. The

suppressed. It will not have time to become unsuppressed before another shell impacts the suppression area.

Equation (A-2) is general enough to cover the cases where the area within which the targets are distributed may not be entirely inside the bombardment area ($F_c < 1$). This can occur when the targets are shelled by small target area rules, using artificial dispersion (see Appendix B, Artillery Kill Rates, for an explanation of target area rules and artificial dispersion).

Under these circumstances the area bombarded may be larger or smaller than the target area (the area within which one or more of the individual targets are located), but the coverage of the target area is less than unity. That is, some part of the target area is not expected to be hit at all.

On the other hand, when shelling by large target area rules the area bombarded will be sufficiently large that there is virtually no chance that any part of the target area will be missed. The target area lies entirely inside the bombardment area. Thus, by large target area rules, $f_c = 1$, and eqn (A-2) becomes:

$$f_s = \left(\frac{As}{Ap}\right) \times \left(\frac{r_f}{60}\right) \times T \qquad \text{(A-5)}$$

where the dimensions of the shelled area, Ap, are approximately the dimensions of the target area itself. Eqn (A-5) is valid when mean firing errors in range and deflection are small relative to the dimensions of the area within which the individual targets are located (see Appendix B for a more rigorous definition).

In the case of elementary and small area targets, $f_c < 1$. Fraction of coverage can be obtained simply by making use of the Soviet formulas given in Appendix B. f_c is not given explicitly by the formulas but can be derived. The resulting expression is:

$$f_c = \left\{ \left(\frac{21(E_{xo})(E_{yo})}{N \cdot A_k} + 0.9 \right) \left(1 - e^{-(N \cdot A_k)/4(1'_x)(1'_y)} \right) \right\}^{-1}$$

methodology below applies only to cases where suppression effects (whether they be from temporary obscuration or the physical heads down reaction to a near miss) last for a fixed time, after which the target becomes unsuppressed until the next near miss again suppresses the target.

A round is said to suppress the target if it lands in a rectangular area in the vicinity of the target such that everywhere within this rectangular area the probability of suppression from the burst is unity. The rectangular area referred to is designated as the suppression area. Suppression implies the defenders are effectively prevented from performing their military duties for a time duration τ.

The fraction of time, f_s, targets are suppressed on the average during a bombardment depends on the tempo of the bombardment and the duration τ of the effects. This can be modelled as:

$$f_s = f_c \times \frac{As}{Ap} \times \frac{r_f}{60} \times \tau \qquad (A-2)$$

where

A_p = Area of the pattern or bombardment rectangle

A_s = Suppression area

f_c = Fraction of coverage of the target area by the bombardment

r_f = Rate of fire (rounds per minute) of the shelling artillery

τ = Duration (seconds) of suppression effects from one shell.

The following restrictions are placed on f_s:

$$o \leq f_s \quad 1 \quad \text{for} \quad \tau < \frac{60}{f_c \times \left(\frac{As}{Ap}\right) \times r_f} \qquad (A-3)$$

$$f_s = 1 \quad \text{for} \quad \tau \geq \frac{60}{f_c \times \left(\frac{As}{Ap}\right) \times r_f} \qquad (A-4)$$

Physically, this means that if τ, the suppression duration, is at least as large as the right hand quantity in eqn (A-4), the target will stay

where:

E_{xo}, E_{yo} = are the mean point of impact errors (repeating errors in Soviet terminology) in range and deflection, respectively.

A_k = lethal area of an elementary target

N = number of rounds to be expended

$21'_x$, $21'_y$ = dimensions of the bombardment rectangle in range and deflection, respectively.

For elementary and small area targets:

$$21_x' = 3.95 \, E_{xo} \left(\frac{p}{1-.9p} \right)^{1/4} \qquad \text{(A-7a)}$$

$$21_y' = 3.95 \, E_{xo} \left(\frac{p}{1-.9p} \right)^{1/4} \qquad \text{(A-7b)}$$

where p is the damage level consistent with the number of rounds to be expended.

When artificial dispersion is employed* against elementary or small area targets:

$$N = 21p(E_{xo})(E_{yo})/(1-.9p) \, A_k \qquad \text{(A-9)}$$

Making use of relations (A-7) and (A-9) in eqn (A-6a) gives the interesting result:

$$f_c = \frac{p}{1-e^{-1.34\sqrt{\frac{p}{1-.9p}}}} \qquad \text{(A-6b)}$$

Thus the fraction of coverage is a function only of p when artificial dispersion is used. Figure A-5 is a graph of this relationship.

The procedure for calculating the suppression factor is as follows: Determine whether the bombardment is conducted under large target area rules or small target area rules (refer to Appendix B). If it is conducted under large target rules, eqn (A-2) can be used directly with $f_c = 1$.

---

* Against an observed target, $N = \dfrac{\ln(1-P)}{\ln(1-P_{kss})}$ where P_{kss} is single shot kill probability.

Fraction of Coverage
Against Small Area Target

or

Probability That Elementary
Target is Within the
Bombardment Area.

FRACTION OF COVERAGE

FRACTION OF DAMAGE
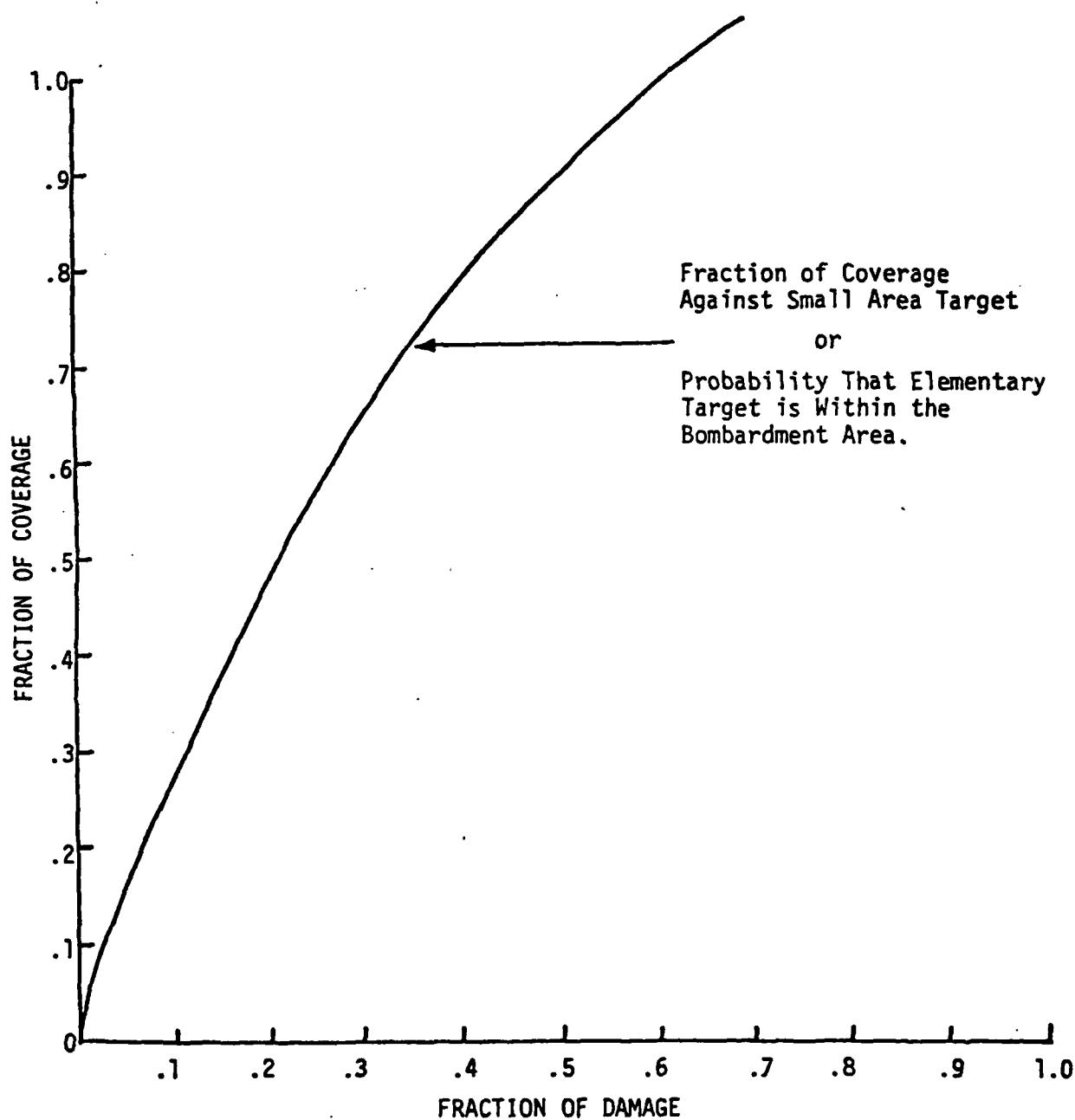
Figure A-5. Fraction of Coverage Using Artificial Dispersion

The values of the other parameters depend on the conditions of the bombardment. The bombardment area dimensions are calculated using eqn (B-7) of Appendix B.

If the bombardment is to be conducted under small area target (or elementary target) rules, the target area damage level (probability of damage against an elementary target) is first calculated using eqn (A-1) if the number of rounds is specified. If the damage level is specified it must be consistent with the number of rounds to be expended. This value of p is substituted into eqn (A-6b) to give f_c. The bombardment dimensions are obtained from eqn (A-7). Then f_s is computed. The suppression factor S is just: $S = 1 - f_s$. (A-8)

EXAMPLE 2

PROBLEM :

Fire from an artillery battery is delivered against a heavy weapons bunker (with firing apertures facing the front), at a mean rate of 7 rounds per minute, in an attempt to neutralize the objective (attain a 20-25 percent probability of target kill).

Assume the suppression area is a rectangle in front of the target with dimensions $2l_x$ = 24m, $2l_y$ = 10m. An impact of a shell within this area suppresses the bunker for 30 seconds. What is the suppression factor, S, if mean point of impact errors (repeating errors) are E_{xo} = 60m, E_{yo} = 30m?

SOLUTION :

The objective is an elementary target. The first step is to obtain the approximation for f_c. By Soviet standards, neutralizing an objective means obtaining a 20-25 percent probability of target kill. For definiteness, we will specify 25%. Then we calculate the dimensions of the bombardment area from eqn (A-7) :

$$2L'_x = 3.95(60)\left[\frac{.25}{1-(.9)(.25)}\right]^{1/4} = 180m$$

$$2L'_y = 3.95(30)\left[\frac{.25}{1-(.9)(.25)}\right]^{1/4} = 90m$$

By formula (A-6b) :

$$f_c = \frac{.25}{1-e^{-1.34\sqrt{\frac{.25}{1-(.9)(.25)}}}} = .47$$

Finally, we substitute this into eqn (A-2) with:

$$A_p = 4L'_x L'_y = (180)(90) = 16200m^2.$$

From the conditions of the problem, the rate of fire is 7 rpm, suppression area As = 24 x 10 = 240m², suppression T = 30 sec. Thus, by eqn (A-2) :

$$f_s = (.47)\left(\frac{240}{16200}\right)\left(\frac{7}{60}\right)(30) = .024$$

$$S = 1 - f_s = .98.$$

EXAMPLE 3

PROBLEM :

An artillery battalion is shelling a company of tanks deployed in an area of dimensions $2 L_x = 500m$, $2 L_y = 400m$. Determine the suppression factor if 600 howitzer rounds are fired in a one hour bombardment at a range such that mean point of impact (mean repeating) errors in range and deflection are respectively $E_{xo} = 30m$, $E_{yo} = 10m$. Assume a suppression area about the tank has rectangular dimensions $21_x = 29m$, $21_y = 23m$, minus an assumed lethal area of $40m^2$. The impact of a shell within this area suppresses the tank for 30 seconds.

SOLUTION:

The repeating errors are much smaller than the objective area and satisfy the criteria of eqn (A-5), that is $2 L_x$ 15 E_{xo}, $2 L_y$ 15 E_{yo} . Thus, the target objective is a large area target. We calculate L'_x, L_y', the half dimensions of the bombardment area from eqn (A-7) :

$$L_x' = L_x \sqrt{1 + 6.6\left(\frac{E_{xo}}{L_x}\right)} = 262m \qquad L_y' = L_y \sqrt{1 + 6.6\left(\frac{E_{yo}}{L_y}\right)} = 206m$$

The area of the pattern is $4 \times 262 \times 206 = 215,888m^2$. The suppression area is $(29 \times 23) - 40 = 627m^2$. From the conditions of the problem, the rate of fire is seen to be :

$$r_f = \frac{600 \text{ rounds}}{60 \text{ min}} = 10 \text{ rounds/min}$$

The duration of the effects, , has been given as 30 seconds. Since the objective satifies the large area target criteria, the fraction of coverage, $F_c = 1$. This is because the area bombarded is large enough so that there is virtually no chance the target area is not entirely included in the bombardment area.

Hence, substituting these values into eqn (A-2) :

$$f_s = (1) \times \left(\frac{627}{215,888}\right) \times \frac{10}{60} \times (30) = .015$$

The suppression factor is simply :

$$S = 1 - .015 = .985.$$

In shelling a large area target (indeed any target), the number. of rounds expended for suppression must be consistent wit the target damage level p as well as the ammunition on hand. For a specified level of damage p , the number of rounds expended can be determined by solving eq (A-6) for N:

$$N = \frac{4L_x{'} \; L_y{'}}{A_k} \; \ln(1-p) \qquad\qquad\qquad (A-10)$$

where $L_x{'}$, $L_y{'}$ are half the dimensions of the objective area after correcting for mean repeating errors using formula (A-7).

A_k = lethal area of an elementary target within the bombarded area.

From the conditions of example A-3 above, if the level of damage had been specified (instead of the number of howitzer rounds) as p = .11, with a 40m^2 lethal area for a tank:

$$N = \left(\frac{-4(262)(206)}{40}\right) \ln(1-.11) \quad = \quad 600 \text{ rounds (approx.)}$$

The suppression calculation would then proceed as illustrated in the example.

      b.   Long Duration Suppression

               Longer duration suppression, as pointed out previously, involves a complicated optical density function at the wavelength of interest. To simplify calculations in the Battle Book method, a convenient way of representing "generalized" visibility degradation is to reduce a tactical firing rate by some fixed amount, e.g. 50%. This quantity may be obtained by data from more sophisticated models, or used as an intuitive estimate by the analyst or commander conducting the play.

5.   PROBABILITY OF KILL

The third critical value in the kill rate equation is the probability of killing a target given a single shot (P_{kss} at a live target). Many factors affect this probability, including, of course, target and firing weapon type, as well as target aspect, target motion, range, and degree .of defilade.

The U.S. Army Material Systems Analysis Agency (AMSAA) has published detailed kill probability data on various armor/anti-armor. weapon pairs. These data are comprehensive and internally self consistent, and the recommended data base for Battle Book kill rate methodology.

A typical probability of kill curve as a function of range is shown in Figure A-5. Because the $P_{k_{ss}}$ curve often shows a strong dependency on range, it is normally used to assign "range zones". The range zone width is chosen so that there is roughly a consistent change in P_k from one zone to the next, i.e., the faster the P_k curve change, the more zones are needed to accurately describe the function. This is illustrated in Figure A-5, where zones 2 and 3 are 300m in depth, in the regions where P_k changes rapidly with range. The assignment of average P_k in each zone is illustrated in the accompanying table.

BATTLE BOOK II METHODOLOGY USES RANGE ZONES TO ACCOUNT FOR RANGE DEPENDENCY OF P_K

ZONE	RANGE	P_K
1	0-400	.7
2	400-700	.60
3	700-1000	.35
4	1000-1500	.15
5	1500-2000	.08
6	2000-2500	NA
7	2500-3000	NA

- ADJUSTABLE RANGE ZONES
- NARROWER ZONES WHERE P_K CHANGE IS LARGE
- AVERAGE P_K DERIVED FOR EACH ZONE
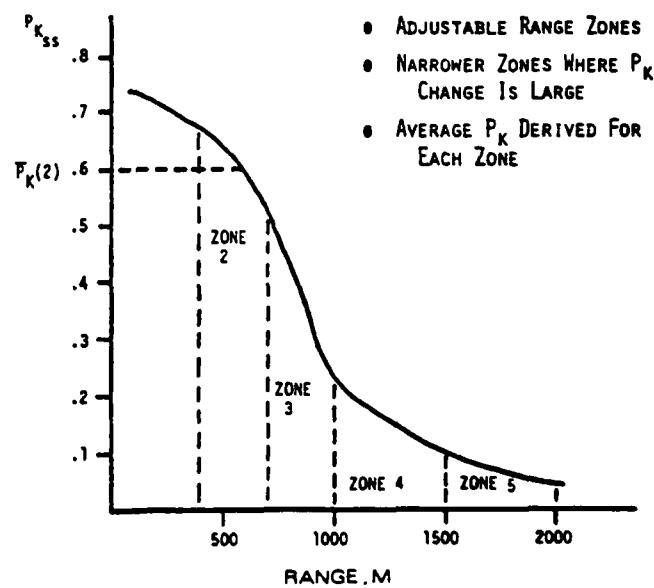
FIGURE A-5

6. TARGET FACTOR "T"

The target factor "T" degrades the single shot kill probability due to three factors: target in partial defilade; dead targets; imprecisely located and nonexistant targets. For convenience, dead, nonexistant, and poorly located targets are treated as "fake targets".

a) Defilade Targets

The AMSAA data previously referenced treats two cases: fully exposed moving or stationary targets, and stationary targets in defilade (this normally implies hull defilade for a tank). In actual field experiments, it is observed that moving targets tend to be in "defilade" in two cases:

(1) Completely hidden by terrain features, especially vegetation, for certain lengths of time

(2) Silhouette partially obscured by terrain features.

In the former case, the gunner effectively loses track of the target for the time it is out of view. For the latter case, there is effectively a smaller target to observe and shoot at. In principal, the two cases represent entirely different phenomena that modify P_{kss} , and testing is presently underway that will (hopefully) resolve these differences.

In practice, it is formed that a contribution to the target factor of unity to 0.8 is sufficient to modify the kill rate equations to account for this phenomenon. It is recommended that a constant factor be applied to all defending (and sometimes attacking) kill rates to maintain consistency in the calculations.

b) Fake Targets

In the kill rate expression, the false target component of "T" represents the fraction of total firings by an individual weapon system that is directed against valid targets. In order to obtain T, one must account for the firings against false targets (terrain features, empty buildings, shadows, previously killed targets). During an anti/

anti-armor engagement between an advancing threat force and stationary, defiladed defensive force, the threat should generate a higher false target rate than the defense. This is because the defense would, on the average, have more easily identifiable and exposed targets to shoot at, while just the opposite situation would apply for the advancing threat.

False target data was obtained from a study of the armor/anti-armor exchanges in various field experiments. In such experiments, the defenders were generally stationary and concealed, making detection by attacking cres in moving vehicles a difficult problem.

Figure A-6 gives range-averaged estimates of false target factors observed under field experiment conditions. On the whole, the defending weapon systems were able to pair 70 to 80 percent of their rounds against valid targets. Attacking tanks on the average, paired 20 to 30 percent of their total firings against live defending targets. These values can be taken as the basis for the probability of successfully directing pinpoint fire against an individual target, depending on whether the firer is an advancing or defending direct fire system. This probability is equivalent to the false target component of T.

FIGURE A-6. ESTIMATES OF PERCENTAGE OF PAIRED FIRINGS AGAINST VALID TARGETS FOR FIELD EXPERIMENTS

ATTACKERS	T62 TANK	20-30%
	ATGM	20-60%
DEFENDERS	ATGM (TOW/SWINGFIRE)	60-90%
	SHILLELAGH	70%
	DRAGON/MILAN	50-80%
	M60A1/CHIEFTAIN TANK	70%

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APPENDIX B

RED ARTILLERY

1. <u>INTRODUCTION</u>

This appendix gives examples of calculating casualties and kill rates
due to red indirect fire against stationary blue positions. The results
can be applied in Battle Book Calculus in two ways:

(1) Decrement the initial blue strengths by a calculated amount.
This is applicable when the red assault is preceded by a pre-
paratory fire.

(2) Decrement the blue faces minute-by-minute during the battle,
using an average kill rate due to supporting indirect fires.
The calculation of average kill rates is shown in several
examples in this Appendix.

Two different cases are treated in this Appendix: unobserved fire
using "artificial dispersion" to maximize kill probabilities, and ob-
served fire with adjustment. The analyst must choose which case to use,
depending on his particular battle scenario.

2. OVERVIEW OF RED ARTILLERY DOCTRINE

The methodology presented in this Appendix is based on Soviet formulas to calculate fractional damage achieved by artillery shelling observed and unobserved targets. Emphasis is on the shelling of unobserved targets by means of artificial dispersion. This concept is discussed in References 1 and 2. Briefly, artificial dispersion means varying the range and azimuth settings (changing the aimpoints) of a gun or battery so as to cover a larger area than could otherwise be done with one setting. This is necessary if the mean errors in generating initial firing data are greater than mean errors in natural burst dispersion, or if the dimensions of the target area are much larger than the natural dispersion of the impacting rounds.

The Soviets conduct fire missions against one or more elementary targets. In Soviet terminology an elementary target is an entity which cannot be further subdivided without disturbing its physical integrity. Individual tanks, APC's, artillery pieces, bunkers, etc., are examples of elementary targets. The objective of an artillery fire mission is usually an area containing a distribution of one or more elementary targets. The Soviets represent these areas as rectangular figures, with one of the sides oriented in the direction of fire. The width of the target area perpendicular to the direction of fire is designated $2 L_y$ and the dimension aligned parallel to the direction of fire is $2 L_x$.

SOVIET ARTILLERY DOCTRINE

- Uses <u>ARTIFICIAL DISPERSION</u> to Maximize Kill
  Probabilities of Unobserved Fire Against Various
  Target Types and Arrays.

- Fire Missions Conducted Against One or More
  <u>ELEMENTARY TARGETS</u> Represented as Rectangular Figures.

```
Direction  ↑        2 Ly
   of      |      ┌──────┐
  Fire     |      │      │ 2 Lx
           |      └──────┘
```
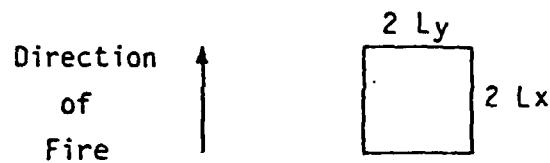
- <u>DIFFERENT CALCULATIONS</u> Apply To:

    - Unobserved Fire on Elementary Targets
    - Unobserved Fire on Small Area Targets
    - Unobserved Fire on Large Area Targets
    - Unobserved Fire on Linear Targets
    - Adjusted Fire on Elementary Targets
    - Adjusted Fire on Linear Targets

3. ARTIFICIAL DISPERSION

The Soviets employ three different formulas to cover three different situations when shelling elementary targets or target areas by means of artificial dispersion. The three situations are:

(1) An elementary target is shelled where the mean errors in generating initial firing data (repeating errors in Soviet terminology or mean point of impact errors in U.S. terminology) are larger than the natural dispersion errors (nonrepeating errors in Soviet terminology or precision firing errors in U.S. terminology).

(2) A small area target is shelled within which are several unobserved elementary targets. Examples of a small area target are an artillery battery or a defending tank platoon in defilade.

(3) A large area target is shelled within which are a group of unobserved elementary targets, or one elementary target if there is a large uncertainty in its location. All errors, repeating and nonrepeating, are small compared with the target area dimensions. The area bombarded is sufficiently large that there is virtually no chance that any part of the target area is not included in the bombardment.

The formulas that follow are taken from Reference 1 and reflect the results of Soviet studies to optimize the method of shelling to obtain the theoretical maximum target damage for a given expenditure of shells when employing artificial dispersion.

THREE PRINCIPAL CASES AGAINST UNOBSERVED TARGETS
(Artificial Dispersion)

1. **ELEMENTARY TARGET**

   - Target Location Not Pinpointed
   - Mean Point of Impact Errors Greater Than
     Natural Dispersion

   Example: Bunker

2. **SMALL AREA TARGET**

   - Cluster of Elementary Targets with
     Reasonably Well Known Location
   - Elementary Target Sizes Small Compared
     To Natural Dispersion

   Examples: Tank Platoon in Defilade; Artillery Battery

3. **LARGE AREA TARGET**

   - Elementary Target with Large Uncertainty
     in Location
   - Multiple Elementary Targets in a Large Area

   Example: Dispersed Tank Company

4. UNOBSERVED FIRE ON ELEMENTARY TARGETS

When firing several rounds with optimal artificial dispersion, the
probability of target kill against an unobserved elementary target can be
calculated from formula B-1:

where A_k is the lethal area of the elementary target (rectangular
             area everywhere within which a bursting shell will kill the
             elementary target with unity probability.   In Soviet ter-
             minology this is called the 'Corrected Effective Hit Zone').

             E_{xo} , E_{yo} are mean repeating errors (range error probable,
             deflection error probable, respectively, in mean point of
             impact) due to inaccuracy of initial firing data.

             N is the number of rounds to be fired over the duration of
             the bombardment.

It is usually the case that mean errors in the initial firing data
(repeating errors) are greater than the ballistic dispersion errors (non-
repeating errors) by factors of two or three to one when artillery is
firing against unobserved targets. These errors are approximately the
same only after fire has been adjusted onto a target (usually by a for-
ward observer). Against unobserved targets, artificial dispersion is al-
most always justified.

UNOBSERVED FIRE ON ELEMENTARY TARGETS

PROBABILITY OF KILL DURING BOMBARDMENT:

$$P = \left(\frac{21 \cdot (E_{xo}) \cdot (E_{yo})}{N \cdot A_v} + 0.9 \right)^{-1} \tag{B-1}$$

Where: E_{xo}, E_{yo} are mean repeating errors (meters)

N   is number of rounds in bombardment

A_v is target lethal area (square meters)

AVERAGE KILL RATE (KILLS/MINUTE)

$$R_K = \frac{P}{t} \tag{B-2}$$

Where: t   is the bombardment time (minutes)

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EXAMPLE 1

UNOBSERVED FIRE ON ELEMENTARY TARGET

PROBLEM:

Shells are fired in an optimal manner using artificial dispersion against a sheltered forward command post. Determine the damage rate per minute against the command post if at the range of interest the mean repeating errors (mean point of impact errors) are E_{xo} = 30m, E_{yo} = 10m in range and deflection, respectively. Assume the battery is firing at a sustained rate of 6 rounds per minute for one hour. Take the lethal area of the command post to be 30m^2.

SOLUTION:

Since the target is to receive fire utilizing artificial dispersion, we can apply eq (B-1) with A_k = 30m^2 and N = 6 rpm x 60 min = 360 rounds.

$$P = \left(\frac{21 \cdot 30 \cdot 10}{360 \cdot 10} + 0.9 \right)^{-1} = 0.67$$

Then, using Eqn B-2, the kill rate per minute = $\frac{0.67}{60 \text{ MIN}}$ = 0.11 $\frac{\text{KILLS}}{\text{MIN}}$

5. UNOBSERVED FIRE ON SMALL AREA TARGETS

In many instances, an elementary or group of elementary targets will be known to lie within an area which is somewhat larger than the initial repeating errors associated with bringing fire to bear. This is the small area target case.

An area target is defined to be small, according to the Soviets, if:

$$2 L_x \leq 15 E_{xo} ; \quad 2 L_y \leq 15 E_{yo} \tag{B-3}$$

where $2 L_x$ and $2 L_y$ are area target dimensions parallel and perpendicular, respectively, to the direction of fire.

The fraction of unobserved targets killed in a small target area is given by the Soviet formula B-4, with E'_{xo} and E'_{yo} computed according to B-5 to take into account the target area dimensions (not the elementary target dimensions).

UNOBSERVED FIRE ON SMALL AREA TARGETS

FRACTION OF TARGETS KILLED DURING BOMBARDMENT:

$$F = \frac{21(E_{xo}')(E_{yo}')}{N \cdot A_v} + 0.9 \qquad (B-4)$$

$$E_{xo}' = E_{xo}\sqrt{1 + 0.15\left(\frac{L_x}{E_{xo}}\right)^2}$$

$$(B-5)$$

$$E_{yo}' = E_{yo}\sqrt{1 + 0.15\left(\frac{L_y}{E_{yo}}\right)^2}$$

Where: E_{xo}, E_{yo} are mean repeating errors (meters)

L_x, L_y are elementary target dimensions

N is number of rounds in the bombardment

A_v is target lethal area (square meters)

EXAMPLE 2
UNOBSERVED FIRE ON SMALL AREA TARGET

PROBLEM:

Determine the expected fractional kill rate per minute inflicted by a red artillery battalion conducting counter battery fire for a quarter of an hour at a rate of 20 rounds per minute against a self propelled artillery battery. The target battery is known to be deployed in a rectangular area $2 L_x = 80m$, $2 L_y = 300m$. Mean repeating errors at the range of interest are $E_{xo} = 100m$, $E_{yo} = 35m$. Assume the lethal area of an individual SP gun is $50m^2$ when shelled by medium caliber artillery.

SOLUTION:

The objective is a small area target by the criteria:

$$80 \leq 15 \times 100; \quad 300 \leq 15 \times 35$$

Then by formula (B-4)

$$E_{xo}' = 100 \sqrt{1 + 0.15 \left(\frac{40}{100}\right)^2} = 101 \text{ m.}$$

Also $A_k = 50m^2$, N = 20rpm x 15 min = 300 rounds.
Application of formula (B-3) gives

$$F = \left(\frac{21(101)(68)}{(300)(50)} + 0.9\right)^{-1} = 0.095$$

Artillery Kill Rate Per Minute (from B-2) = 0.095/15 = 0.006 kills/min.

EXAMPLE 2, CONTINUED

The remaining firepower of the shelled targets, after each minute of bombardment, can be obtained as follows. Multiply the fractional damage or kill rate per minute by the initial number of targets. This amount is then subtracted from the previous number remaining, each minute. Thus, using the conditions of Examples 2, assume initially the target battery consists of 6 guns. At the end of the first minute of bombardment, remaining firepower = 6 - (.006)(6) = 5.96 (approximately). At the end of the second minute, remaining firepower = 5.96 - (.006)(6) = 5.92 (approximately). At the end of the third minute, remaining firepower = 5.92 - (.006)(6) = 5.88 (approximately). And so on.

6. <u>UNOBSERVED FIRE ON LARGE AREA TARGET</u>

An area target is defined to be large if:

$$2L_x > 15E_{xo} \quad ; \quad 2L_y > 15E_{yo} \qquad \text{(B-6)}$$

The area target is sufficiently large that the probability of each round impacting the area is essentially unity. The area bombarded is effectively equivalent to the target area. Under these circumstances the Soviets use formula (B-7) to determine the fractional damage to 1 or more elementary targets in the target area.

L'_x and L'_y given by (B-8) are one half of the "adjusted" target dimensions in the x and y directions (parallel and perpendicular to the axis of fire) respectively, after corrections for mean repeating errors. Reference 2 points out that eqn (B-8) is a relatively minor correction since L'_x (or L'_y) can never exceed L_x (or L_y) by more than 6% if it is to satisfy the definitions of a large area target.

UNOBSERVED FIRE ON LARGE AREA TARGETS

FRACTION OF TARGET KILLED DURING BOMBARDMENT:

$$F = 1 - e^{-(N \cdot A_v / 4(L_x')(L_y'))} \tag{B-7}$$

Where

$$L_x' = L_x \sqrt{1 + 6.6 \left(\frac{E_{xo}}{L_x}\right)^2}$$

$$\tag{B-8}$$

$$L_y' = L_y \sqrt{1 + 6.6 \left(\frac{E_{yo}}{L_y}\right)^2}$$

Where: E_{xo}, E_{yo} are mean repeating errors (meters)

L_x, L_y are area target dimensions

N is the number of rounds in the bombardment

A_v is the lethal area of the elementary target(s) in the target area

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EXAMPLE 3
UNOBSERVED FIRE ON A LARGE AREA TARGET

PROBLEM:

An enemy tank company is known to be dispersed within an area of dimensions $2 L_x = 500m$, $2 L_y = 400m$. Determine the kill rate per minute from 600 howitzer rounds fired in a one hour bombardment at a range such than the mean repeating errors in range and deflection are respectively $E_{xo} = 30m$, $E_{yo} = 20m$. Assume the lethal area of a tank is $40m^2$.

SOLUTION

Since the repeating errors are much smaller than the area bombarded, and satisfy the criteria of eqn (B-6), the target objective is a large area target.

From eqn (B-8) :

$$L_x' = 250\sqrt{1 + 6.6(30/250)^2} = 250 \times 1.05 = 262 \text{ m.}$$
$$L_y' = 200\sqrt{1 + 6.6(20/200)^2} = 200 \times 1.03 = 206 \text{ m.}$$

Then by eqn (B-7) $F = 1 - e^{-(600)(40)/4(262)(206)} = 0.10$

The kill rate per minute $= .10/60 = .0017$. Thus, from the conditions of the problem each tank has subtracted from its initial target value of one an amount equal to .0017 units each minute of the bombardment.

7. UNOBSERVED FIRE ON LINEAR TARGETS

To determine fractional kill when firing at linear targets with artificial dispersion, the previous formulas are utilized with either $2L_x = 0$ or $2L_y = 0$, depending on the orientation of the objective relative to the direction of fire (the objective must be either aligned with the direction of fire or oriented perpendicular to it for the formulas to be applicable).

EXAMPLE 4
UNOBSERVED FIRE ON LINEAR TARGETS

PROBLEM:

Determine the kill rate per minute inflicted on a halted column of ten armored personnel carriers, 300m in length, by fire from a battalion of 122mm howitzers employing artificial dispersion. Repeating errors at the range of the shelling are $E_{xo} = 62m$, $E_{yo} = 23m$, in range and deflection respectively. The direction of the column is approximately perpendicular to the direction of fire. Ammunition expenditure is 400 rounds during a 20 minute bombardment. A 122mm shell will destroy an APC if it bursts within an area of $50m^2$ centered at the target.

SOLUTION:

From the conditions of the problem $2 L_x = 0$, $2 L_y = 300m$, $A_v = 50m^2$. Since the length of the column, $2 L_y$, is less than $15 E_{yo}$, the objective is defined to be a small area target and the fractional kill is found with formula (B-4). First, the values of E'_{xo}, E'_{yo} are determined from formula (B-5):

$$E_{xo}' = 62 \sqrt{1 + .15 \, (0)^2} = 62 \text{ m.}$$

$$E_{yo}' = 23 \sqrt{1 + 0.15(150/23)^2} = 63 \text{ m.}$$

consequently, by eqn (A-3):

$$F = \left(\frac{(400)(50)}{21(62)(63)} + 0.9 \right)^{-1} = 0.20$$

Kill rate per minute = $0.20/20 = 0.01$

If there are 10 APC's in the column then the average number destroyed per minute is $10 \times 0.01 = 0.1$.

8. ADJUSTED FIRE ON ELEMENTARY TARGETS

Artificial dispersion is employed in shelling area targets and un-
observed elementary targets. After fire is adjusted onto a target by a
forward observer, the use of artificial dispersion is no longer warranted.
Mean point of impact errors (meant repeating errors in Soviet terminology)
do not exceed mean dispersion errors (mean nonrepeating errors in Soviet
terminology) and it is more advantageous to fire at the center of the
elementary target with one range and azimuth setting. Under these cir-
cumstances the cumulative probability of target kill is given by (B-9).

It is assumed that each round has the same probability of achieving a
kill as any other round. To kill the target the round must be fired into
a rectangular area about the center of the target (the Soviets prefer rec-
tangles to circles) which is precisely the lethal area (corrected effective
hit zone in Soviet terminology) of the target. (If the lethal area is not
rectangular to begin with, the Soviets will correct it to a rectangle be-
fore applying their formulas). This is defined to be the area everywhere
within which the probability of kill from a bursting shell is unity.

Let $2 \, l_x$, $2 \, l_y$ be the rectangular dimensions of the lethal area of
the target in range and deflection respectively. The probability, P_{kss},
that a round will kill the target is equivalent to the probability of it
impacting inside the desired rectangle. If the round is aimed at the tar-
get in the center (whose dimensions may or may not coincide with those
of the lethal area), the required probability is given by eqn. (B-10).

Formula (B-10) can easily be evaluated without complicated mathema-
tical computations by the use of Figure B-1. The quantities

$$\Phi(l_x/REP) \qquad \text{and} \qquad \Phi(l_y/DEP)$$

are each, in turn, read off Figure (A-1) for the appropriate

values of l_x/REP and l_y/DEP respectively. These quantities are then
multiplied together as indicated by eqn. (A-11) to obtain P_{kss}. Values
for REP and DEP can be obtained from firing error tables (or by combining
the component errors as shown). Lethal area dimensions will vary, depending
on target shape, protection, and caliber of shelling artillery.

ADJUSTED FIRE ON ELEMENTARY TARGETS

CUMULATIVE PROBABILITY OF KILL:

$$P = 1 - (1 - P_{kss})^N \qquad (B-9)$$

SINGLE SHOT PROBABILITY OF KILL:

$$P_{kss} = \Phi (1_x/REP) \cdot \Phi (1_y/DEP) \qquad (B-10)$$

Where: N is the number of rounds fired;

$\Phi (1_x/DEP)$ is probability of impact in an interval $(-1_x, 1_x)$;

$\Phi (1_y/DEP)$ is probability of impact in an interval $(-1_y, 1_y)$;

These functions may be read directly from Fig. B-1.

and 1_x, 1_y are half the dimensions of the lethal area in range and deflection respectively.

REP, DEP are range error probable and deflection error probable which measure the distance from the center that will include, on the average, 50 percent of the impact points in range and deflection respectively. These are calculated from ballistic dispersion data, as shown on the next chart.

Figure B-1. PROBABILITY OF IMPACT IN INTERVAL (-1, 1)
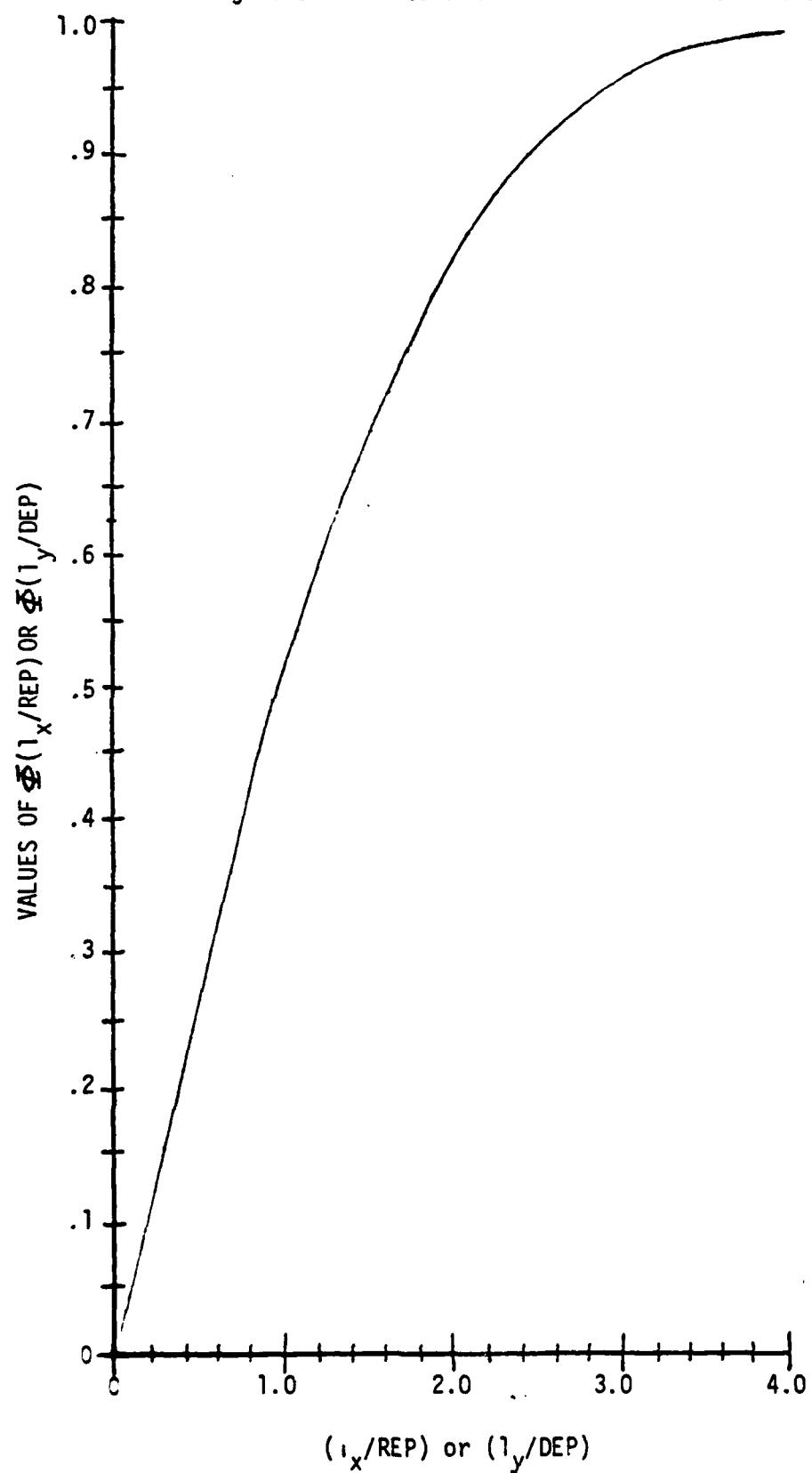
ADJUSTED FIRE ON ELEMENTARY TARGETS

-IMPACT PROBABILITIES-

RANGE ERROR PROBABLE

$$REP = \sqrt{E_{xo}^2 + (Bd_o)^2} \qquad (B-11)$$

DEFLECTION ERROR PROBABLE

$$DEP = \sqrt{E_{yo}^2 + (BD_o)^2} \qquad (B-12)$$

Where: E_{xo}, E_{yo} are the mean point of impact

errors (repeating errors) in

range and deflection respectively.

Bd_o, BD_o are the mean dispersion errors

(non repeating errors) in range

and deflection respectively.

Examples of E_{xo}, E_{yo}, Bd_o, and BD_o for typical

Soviet systems are given in Section 8.

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EXAMPLE 5
ADJUSTED FIRE ON AN ELEMENTARY TARGET

PROBLEM:

Determine the probability of destroying a casemate after adjustment of battery fire if 40 122mm howitzer shells are expended. After adjustment, the mean firing errors are $2\ l_x = 5m$, $2\ l_y = 4m$.

SOLUTION:

From the conditions of the problem $E_{x\bar{o}} \leqslant Bd_o$, $E_{yo} \leqslant BD_o$. The target is shelled without artificial dispersion, and the individual rounds can be considered independent, each with a kill probability, P_{kss}. This is obtained as follows:

From formula (B-12):

$$REP = \sqrt{(20)^2 + (25)^2} = 32\ m.$$

$$DEP = \sqrt{(4)^2 + (4.5)^2} = 6\ m.$$

Then

$$l_x/REP = 2.5/32 = .08$$

$$l_y/DEP = 2/6 = .33$$

From Figure B-1

$$\phi(l_x/REP) = \phi(.08) = 0.04$$

$$\phi(l_y/DEP) = \phi(.33) = 0.17$$

Then $P_{kss} = (.04)\cdot(.17) = .007$

Finally by formula (B-10) for N = 40 rounds:

$$P = 1 - (1 - .007)^{40} = 0.25$$

(If 40 rounds were fired by the battery over a 5 minute period the fraction of damage per minute is $= .25/5 = .05$).

9. ASSUMED FIRING DATA TO CALCULATE EFFECTS OF ARTILLERY

The preceding sections outlined the methodology to calculate kill rates due to the effects of indirect fire. It was assumed that the analyst had access to appropriate input firing data and lethal area data either from test results, firing tables or other pertinent published literature, in order to apply the formulas. Information may be difficult to come by for Soviet weapons so the following approximations are suggested in the absence of better data.

Firing errors are a function of range, but it is standard practice in war game simulations to assume "off board" artillery is firing at 2/3 maximum range. At this range, the values given in Table B-1 can be considered representative of Howitzer System firing errors for unadjusted fire:

MEAN POINT OF IMPACT ERROR (MILS)		MEAN DISPERSION ERROR (MILS)	
E_{xo} (RANGE)	E_{yo} (DEFLECTION)	Bd_o (RANGE)	BD_o (DEFLECTION)
7.5	3.5	3.0	1.5

Table B-1. Estimated Errors for Unadjusted Fire.

Application of the above values to the 122mm and 152mm Soviet field howitzer systems is shown in Table B-2.

HOWITZER SYSTEM	2/3 MAX RANGE (METERS)	MPI ERROR (METERS)		MEAN DISPERSION ERROR (METERS)		WEAPON BASIC LOAD
		E_{xo}	E_{yo}	Bd_o	BD_o	
122mm D-30	10,000	75	35	30	15	80
152mm D-20	12,000	90	42	36	18	60

Table B-2. Estimated Firing Errors for Soviet Howitzers.

The lethal area of an elementary target may be small or comparatively large, depending on the projectile caliber, type of warhead, fuze setting, burst height, and target protection. In the absence of more authoritative data, Table B-3 may be used to approximate lethal areas of sheltered and armored targets relative to 122mm and 152mm projectiles. Lethal areas for the 122mm case are taken from Reference 1. Lethal areas for the 152mm case are extrapolated.

TARGET	LETHAL AREA (M^2)	
	122MM	152MM
Tow Bunker	15	20
Foxhole	30	50
Tank	40	50
APC	50	62

Table B-3. Estimated Lethal Areas

Utilizing the above data from Tables B-2 and B-3, representative artillery kill rates have been calculated against unobserved elementary targets for a bombardment duration of 60 minutes.

Assumed mean battery rate of fire is 8 rpm for the 122mm battery and 4 rpm for the 152mm battery. There are six guns in each battery. Results are presented in Table B-4

DEFENDING ELEMENTARY TARGET	122MM HOWITZER		152MM HOWITZER		COMPOSITE SHELLING
	SINGLE BATTERY SHELLING	TWO BATTERIES SHELLING	SINGLE BATTERY SHELLING	TWO BATTERIES SHELLING	SINGLE 122MM BATTERY PLUS SINGLE 152MM BATTERY SHELLING
Tow Bunker	.0019	.0035	.0010	.0018	.0027
Foxhole	.0035	.0059	.0022	.0040	.0050
Tank	.0044	.0071	.0022	.0040	.0057
APC	.0052	.0081	.0026	.0047	.0066

Table B-4. Atilllery Kill Rates/Minute for a One Hour Bombardment at 2/3 Maximum Range.

10. <u>REFERENCES</u>

1.   Methods For <u>Calculating Combat Effectiveness of Armament</u>, N.M. Fendrikov, V.I. Yakovlev, JPRS 56631, July 1972.

2.   <u>Soviet Methods of Utilizing Artillery</u>, B. Dunn, BDM Corporation, May 1976.